Biological Criteria for the Recovery of Florida Scrub-Jay Populations on Public Lands in Brevard County and Indian River County

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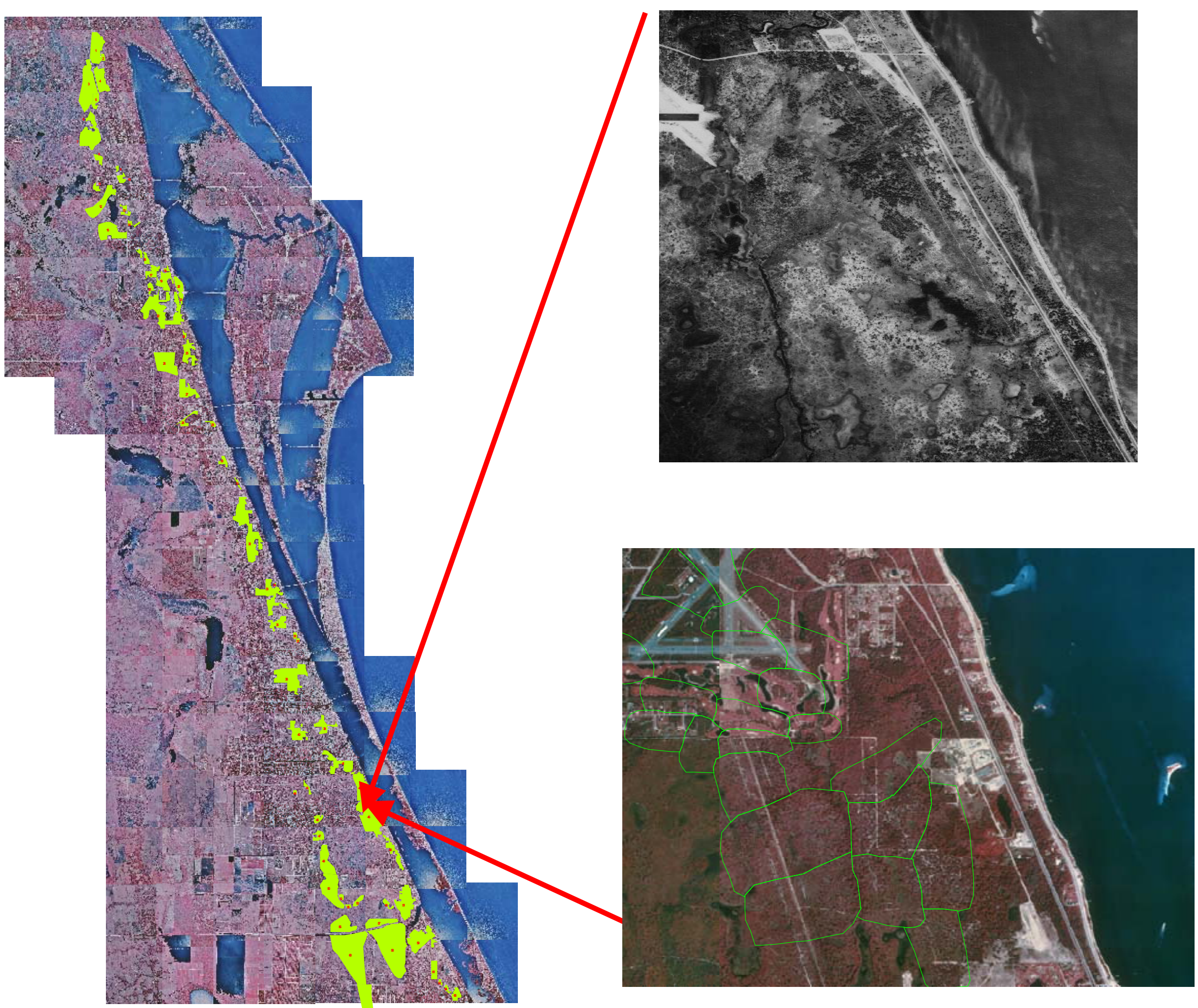


Abstract and Executive summary

Caption 1. The Florida Scrub-Jay is the only bird species unique to Florida.

Introduction The Florida Scrub-Jay (*Aphelocoma coerulescens*) is vulnerable to extinction because of habitat destruction, degradation, and fragmentation (Woolfenden and Fitzpatrick 1991, Root 1998, Breininger et al. 1999a, Stith 1999). This study of Florida Scrub-Jays, funded by the U.S. Fish and Wildlife Service, focuses on existing and proposed nonfederal conservation areas along Florida's central Atlantic coast. The central Atlantic Coast has 3 of the 7 largest Florida Scrub-Jay metapopulations (Stith 1999). This study investigates 4 of the 5 metapopulations that occur along the central Atlantic Coast. The 4 studied are North Brevard, Central Brevard, South Brevard-Indian River-St. Lucie, and South Beach. The 5th metapopulation along Florida's central Atlantic Coast is the federally-owned Merritt Island-Cape Canaveral population.

Objectives The objectives of this empirical study were to:

a) quantify habitat and describe population structure,
b) provide data to prioritize mitigation and land acquisition strategies,
c) quantify habitat-specific demography (e.g., juvenile production, yearling production, breeder survival, helper survival),

d) quantify dispersal (site tenacity, pair bond fidelity, delayed breeding characteristics, dispersal distances, population exchanges among habitat fragments),
e) evaluate habitat quality and identify habitat restoration and management needs,
f) quantify the colonization of restored and uninhabited habitat,
g) identify inventory criteria that identify habitat conditions where potential breeder production equals or exceeds breeder mortality.

The first major section of this report focuses on the geographic distribution of the habitat and the population. The second major section focuses on demography and dispersal of color-banded birds to develop a habitat-based recovery strategy. The final major section summarizes data relevant to habitat management, land acquisition, mitigation, and recovery. Minor sections include an executive summary, introduction, a technical approach, an update of the nearly extinct South Beach barrier island metapopulation, acknowledgements, and a literature cited section.

Geography of Habitat and Population Trends We remapped habitat from south Volusia County to Wabasso on the Atlantic Coastal Ridge and south to State Route 60 on the Ten Mile Ridge in Indian River County because existing landcover maps failed to identify much potential habitat. We aggregated patches of potential habitat that were large enough to support at least one territory into Potential Reserve Units (PRUs). We refined critical habitat polygons described by Stith (1999) because high-resolution digital imagery is now of greater quality and easier to use than was previously available. We overlaid existing and proposed conservation lands to determine how much of each PRU was in conservation ownership or proposed ownership. We used imagery to estimate how much habitat was lost between 1994 and 1999 in PRUs, but not among all scrub patches. We computed the number of territories that could occur in each PRU and evaluated their habitat quality.

Previous conservation analyses only considered xeric oak but more recent studies indicate that palmetto-oak can support Florida Scrub-Jay populations (Breininger et al. 1991a, 1995; Breininger and Oddy 2001). Mapping herein showed that there was enough xeric oak to support 354 territories. Including palmetto-oak provided an estimated population size of 870 territories. Within PRUs, enough habitat was conserved for approximately 267 breeding pairs, and proposed land acquisition programs could conserve another 207 pairs. There were approximately 3686 ha of xeric oak and palmetto-oak located in small habitat fragments outside PRUs. Existing and proposed reserves were poorly connected, and did not represent the geographic distribution of Florida Scrub-Jay habitat.

During this study, several new large populations were discovered and some populations were found to have more potential than previously thought. The locations of unoccupied habitat and occupied territories were not fixed so that we assumed the population was better described using existing locations of Florida Scrub-Jays supplemented by adjacent suitable habitat. Instead of the 1992 polygons that are usually used to describe Florida Scrub-Jay populations (Swain et al. 1995, Stith et al. 1996), we derived “potential territory clusters” to describe geographic structure. We began identifying potential territory clusters by overlaying the 1992 polygons, territory boundaries, and new sightings of Florida Scrub-Jays on habitat maps and aerial photographs. We then aggregated suitable habitat patches into potential territory clusters if they were <2 territory widths from each another or known occupied locations, providing the matrix between suitable patches was conducive to dispersal. This process enlarged and combined many 1992 polygons into larger areas in which we assumed jays would routinely evaluate habitat for dispersal opportunities.

Buffering operations based on dispersal propensities (Stith et al. 1996) were then used to evaluate 3 scenarios of subpopulation and metapopulation structure based on habitat potential, current conditions, and rapid urbanization that characterizes the region (Duncan et al. unpublished data). Based on potential habitat, results suggested that the mainland metapopulations could be viewed as one metapopulation that comprised 407 breeding pairs. Therefore, the population in 1992 was as large as the size used to define core populations (Stith et al. 1996).

Existing habitat and documented dispersals suggested that the three metapopulations might currently be best viewed as a North Brevard and South Brevard-Indian River-St Lucie metapopulation, which involved merging Central Brevard with South Brevard. The potential population size of the South Brevard-Indian River-St Lucie metapopulation could exceed 400 pairs and therefore also had recovery potential to be a core population under this scenario. The final metapopulation scenario assumed that the current rate of habitat loss in Central Brevard will continue so that the separation of the 3 metapopulations becomes more distinct.

The current population estimate for North Brevard, Central Brevard, and South Brevard-Indian River-St Lucie metapopulations combined is 288 breeding pairs. These metapopulations were well below carrying capacity because of poor habitat suitability, which was related to an anthropogenic reduction in natural fire regimes and habitat fragmentation. We estimated an average annual population growth rate of 0.96 suggesting a population decline of 4% per year. The population declines were comparable to predictions using population models and habitat-specific data collected elsewhere (Root 1998, Breininger et al. 1996b, 1999a).

Demography and Dispersal We used colorbanding, recruitment, survival, and dispersal studies to quantify population dynamics between Buck Lake and Sebastian Buffer Reserve. The number of territories studied ranged from 80-180 territories because of fluctuations in funding, increases in conservation land ownership, and a presumed epidemic in 1997. Demography studies were performed on 64% of the population by 2001, when 85% of the population had been surveyed to find dispersed individuals and estimate current population size and distribution.

Most colorbanding included existing and proposed conservation lands. However, we also conducted studies in Palm Bay and along Wickam Road, which both were highly fragmented landscapes. Florida Scrub-Jays residing within such areas have been hypothesized to be population sinks that might temporarily supply immigrants to reserves as reserves are restored (Breininger 1999).

Related studies on the nearby Merritt Island/Cape Canaveral metapopulation show that source-sink population dynamics apply within landscapes (Breininger and Oddy 2001, Breininger and Carter 2003). Landscapes can be partitioned into potential territories to determine the habitat arrangements needed for sources to offset demographic losses in sinks. Sources are territories where recruitment exceeds mortality so that emigration can exceed immigration. Sinks are territories where mortality exceeds recruitment and immigration usually exceeds emigration; sinks can persist only by immigration from sources.

Our approach to describe population dynamics began by characterizing habitat-specific demography. We subdivided territories into categories that addressed habitat potential and existing habitat suitability. Oak cover and soils were used to identify 3 categories of decreasing habitat potential (Breininger and Oddy 2001). Oak cover in territories was designated primary if the territory intersected $\geq$0.4 ha of well-drained oak scrub (Breininger and Oddy 2001). Territories were designated secondary if they did not intersect well-drained oak scrub but intersected polygons having $\geq$50% scrub oak cover that were $\geq$0.4 ha. Territories were designated tertiary if they lacked any oak scrub patches $\geq$0.4 ha that had $\geq$50% oak cover. We observed that primary and secondary territories were potential sources (recruitment exceeded mortality) when their height was optimal. We observed that tertiary territories were usually potential sinks (mortality exceeded recruitment) and that jays from sources did disperse into many types of sinks. This was consistent with related studies (Breininger and Oddy 2001, Breininger and Carter 2003).

We used three categories to describe habitat potential of territories based on their context to human-dominated landscapes. Core territories were not adjacent to human housing or hard surface roads. Territories within PRUs but not adjacent to hard surface roads were designated edge territories. Edges included buildings, airports, and golf courses. Territories within suburban areas or adjacent to hard surface roads were classified as suburban. We did not find a significant relation between demography and edge effects probably because height was suboptimal across most core, reserve edge, and suburb territories. We observed that core, edge, and suburb territories had recruitment $\geq$ mortality when their habitat conditions were optimal, but our sample sizes were low for edge and suburban territories that had optimal height. Greater replication of optimal edge territories is needed given that Mumme et al. (2000) found roadside territories to be sinks and Bowman (unpublished) found that territories among low housing densities to be sinks.

We used shrub height arrangements to classify habitat suitability related to recent fire history (Breininger and Carter 2003). Height categories included territories that were all short (<120 cm), optimal (matrix of short and patches 120-170 cm) mix, tall mix (<170 cm and >170 cm), and tall (>170 cm). Optimal territories tended to be sources and short and tall territories tended to be sinks, as expected (Breininger and Oddy 2001, Breininger and Carter 2003). Tall mix territories tended to have recruitment approximately equal to mortality in contrast to Breininger and Carter (2003), but similar to Stevens and Young (2002). Regardless of these small differences, population growth would only have been expected for optimal territories, which should be maximized because reserves are often far below carrying capacity and recovery requires population growth within reserves.

The success of Florida Scrub-Jay recovery efforts are influenced by Florida Scrub-Jay dispersal propensities (Fitzpatrick et al. 1999). We observed that Florida Scrub-Jays rarely divorced and usually remained together between years once they became breeders, although territory boundaries often fluctuated when there were changes in habitat suitability or where habitat was below carrying capacity. When one member of a breeding pair died, the surviving breeder usually stayed within the same territory and formed a pair bond with a new mate. Sometimes, the survivor did not breed. When the surviving breeder did not remain a breeder in the same territory, it often helped in that territory or in an adjacent territory, although a few females moved great distances to breed.

In Palm Bay suburbs, a disruption of normal population structure followed the 1997-1998 epidemic. Many surviving breeders did not find new mates but became floaters, which were rare in most study sites, as expected (Woolfenden and Fitzpatrick 1984, Stith 1999). Exchanges of jays between suburbs and reserves are believed to be one-way; form suburbs to reserves (Thaxton and Hingtgen 1996; R. Bowman personal communications). We found few exchanges between Palm Bay and conservation reserves and hypothesized that nonbreeders might be attracted to larger populations regardless of habitat potential because these clusters have more breeding opportunities than areas with few pairs (see Breininger 1999). In reserves, we often observed that unbanded immigrants were very tame, suggesting they came from suburbs where jays were accustomed to handouts.

We observed exchanges among many of the territory clusters within the South Brevard-Indian River-St. Lucie Metapopulation, where our studies began. We also observed several movements between this metapopulation and the Central Brevard metapopulation. Our study in North Brevard might have been too short to identify movements among clusters in North Brevard. We did not observe any exchanges between North Brevard and Central Brevard metapopulations but suspect they might occur and we suspect that the genetic connection might be important.

Although long distance dispersals were occasionally observed, approximately 91% of the jays that filled territory vacancies filled vacancies in the same territory cluster. Mean natal dispersal distances were 1.0 km for males and 2.8 km for females. Dispersal propensities were too short for jays to assess habitat quality throughout the metapopulation (and often throughout the territory cluster) so that jays did not uniformly distribute themselves in proportion to breeding opportunities throughout the metapopulation. Consequently, many optimal territories that resulted from restoration were unoccupied when they were not contiguous with territories that had helpers.

We made many sociobiological comparisons with studies by Woolfenden and Fitzpatrick (1984). Rates of breeding by one-year-olds were much greater than associated with stable populations because habitat restoration increased breeding opportunities and because mortality in many territories exceeded recruitment thereby providing increased breeding opportunities (Breininger 1999).

Experienced breeders and breeders with helpers had greater demographic success than novice breeders and breeders without helpers. These relationships, combined with low dispersal propensities, contributed to a slow recovery process within restored areas because experienced pairs with helpers accumulated slowly.

There were significant annual differences in demographic rates but the study was too short to quantify interactions with habitat quality. A presumed epidemic resulted in low survival and steep population reductions in 1997-1998. This was observed elsewhere (Breininger [1999]; Breininger [unpublished data]; Stevens and Young [2002]), Reed Bowman personal communication). We did not characterize the results of the 1997 epidemic as different from the other years (e.g., Woolfenden and Fitzpatrick 1984, 1991) because we assumed that we are entering a period of frequent disease outbreaks because of West Nile Virus. Many sentinel chickens in Brevard and Indian River County tested positive for West Nile Virus after field work in this study ended. Subsequent data indicated that Scrub-Jay mortality was excessively high in many locations between July 2002 and April 2003 (Breininger unpublished data).

Recovery Implications and Management Recommendations A large number of territories occurred in palmetto-oak even when territories in xeric oak (primary territories) were vacant because primary territories were often overgrown. Palmetto-oak had a greater propensity to be optimal in the infrequently burned landscapes because it had a greater propensity to burn (Breininger et al. 2002). Most territories restricted to palmetto-oak occurred on secondary ridges. Secondary and tertiary territories enhance population viability even though they are routinely overlooked in environmental assessments (Breininger and Oddy 2001). Although many potential primary territories were unoccupied because they were overgrown, they had potential to contribute most to recovery once restored because territory quality generally increases as oak cover increases providing other habitat conditions are not suboptimal (Breininger et al. 1995, Burgman et al. 2001). Applications that identify suitable and potential habitat should not only include xeric oak scrub but they should include all adjacent palmetto-dominated habitats that include scrub oaks (Breininger et al. 1995, 1998; Duncan et al. 1995). The ability to consider habitat additional to xeric oak scrub can enhance conservation, because there are restricted opportunities for establishing Florida Scrub-Jay population reserves due to rapid urbanization. Because Florida Scrub-Jays have poor long distance dispersal abilities and are potentially subject to edge effects, it is important to maximize the size of a few dozen reserves than to maximize the amount of xeric oak scrub among hundreds or thousands of habitat fragments. Such approaches rely on habitat-specific demography and dispersal data as provided herein. Land managers also agree with this approach because of the difficulty in burning small urban habitat patches.

It is not necessary to explicitly map scrub oak ridges to apply these results. One can grid landscapes into potential territories and categorize the habitat potential to determine the potential arrangements of sources and sinks. Habitat potential and height can be characterized as attributes of territories. Mean demographic rates can approximate the proportion of sink territories that can be supported by source territories, although approximations are best done using population models that consider additional complexities, such as stage-specific vital rates, stochasticity, and catastrophes (Burgman et al. 1993). If population models are not applied to account for stochasticity and epidemics, demographic gains from sources must greatly exceed demographic losses from sinks. More work is needed to identify these corrections.

Most scrub in east central Florida has been destroyed or is highly fragmented (Duncan et al. unpublished). Many Florida Scrub-Jays occur in suburban territories that will probably always be population sinks because of road mortality and poor habitat quality. If edge effects occur, individual PRUs must have enough core territories to offset declines in territories along roads and possibly suburbs. There is great uncertainty about the demographics associated with edge territories. If these edge effects are widespread, conservation reserves are being established in many of the wrong areas because they lack enough core territories to sustain losses along the edges. However, focusing only on the largest reserves results in a considerable contraction of the range and decreases in connectivity among reserves. Until the science improves, it is critical to design reserves that have low edge/area relationships. This can be achieved by purchasing mesic flatwoods and wetlands adjacent to potential territories and burning them frequently because forests also negatively impact habitat suitability (Breininger et al. 1995, Burgman et al. 2001). These matrix habitats can quickly become forests without frequent fire in east-central Florida (Duncan et al. 1999).

The Florida Scrub-Jay population is declining almost everywhere because of habitat destruction and because habitat does not burn enough. Considerable potential remains to maintain populations with low extinction risk but this depends on additional land acquisition and achieving optimal habitat conditions (Root 1998, Stith 1999). There has not been enough work to identify the level of further habitat reduction where populations can no longer be recovered but that point could soon be reached in Central Brevard many metapopulations throughout the range (Stith 1999). Restoration and habitat management must address habitat suitability at the territory scale (Breininger and Carter 2003). Most conservation reserves still had too much tall scrub even though they were recently burned. Territories that included tall scrub are either population sinks or have recruitment that barely matches mortality. Fires will rarely produce a landscape with only optimal territories but restoring landscapes to reverse population declines requires creating and maintaining enough optimal territories to meet population-based objectives. Because most populations are far below carrying capacity, recovery requires increases in population size. Most territories must be optimal for population growth to occur. Although managers sometimes leave buffers along edges, we recommend that the management for optimal territories begin at reserve edges because of the relatively low number of core territories in most large reserves and because edge territories will certainly be sinks if habitat is suboptimal.

Because tall patches are difficult to eliminate by mosaic fires without first cutting them, cutting must be applied to specific patches of tall scrub throughout the landscape or extensive fires must be used to burn all scrub. Florida Scrub-Jay population declines can occur after extensive fires but these can be followed by population growth (Breininger and Oddy 2001). Extensive fires occurring once every 20 years might be useful because they burn nearly all areas, including those resistant to fire (Breininger et al. 2002). These extensive fires will be most useful where tall mix territories have mortality that exceeds recruitment, where populations are below carrying capacity, or where managers lack the resources to perform patch-specific burns. Optimal habitat management will need to be more specific if West Nile Virus outbreaks are frequent.

Short dispersal propensities and infrequent exchanges among reserves must be considered. Population sizes and exchanges in potential reserves north of Wabasso are sufficient so that translocation is unnecessary. Reserves associated with the Buck Lake territory cluster might need translocation. Although many suburban jays are probably eventually doomed to extirpation, they will remain a potential source of birds as reserves become established and restored. Restoration should be prioritized in areas where jays already occur or adjacent to areas that have jays because the recolonization of restored habitat not adjacent to a source of new potential breeders is slow. It is very important to achieve optimal habitat conditions rapidly in small populations given the high rates of population decline and slow recolonization rates.

Table of Contents

Introduction

Most Florida Scrub-Jay *(Aphelocoma coerulescens)* populations are vulnerable to extinction because of habitat destruction, degradation, or fragmentation (Fitzpatrick et al. 1991, Woolfenden and Fitzpatrick 1991, Root 1998, Breininger et al. 1999a, Toland 2000, Stith 1999). Brevard County Environmentally Endangered Lands Program (EELs), St. Johns River Water Management District (SJRWMD), and Florida Department of Environmental Protection (FDEP) provide much potential habitat in east central Florida. Additional purchases are being proposed but money for land acquisition and mitigation must be used where it will have the greatest effect. Nearly all potential reserves require restoration and adaptive management (Swain et al. 1995, Boyle 1996, Breininger et al. 1999a). Much must be learned about restoring Florida Scrub-Jay habitat that has been subject to soil disturbances, fire suppression, and habitat fragmentation. A few prescribed fires generally do not readily restore habitat conditions where reproductive success equals or exceeds mortality (Schmalzer et al. 1994, Breininger et al. 1996b, Schmalzer and Boyle 1998, Duncan et al. 1999, Breininger and Carter 2003).

Species densities are not always indicative of habitats suitable for population persistence because species can be abundant where the habitat cannot sustain their population without immigration (Lidicker 1975, Van Horne 1983, Garshelis 2000). Abundance can actually be a misleading indicator of habitat quality (Van Horne 1983, Hanski 1999). Time lags in population responses can mask the consequences of habitat change for long periods (Pulliam 1988, Howe et al. 1991, Nagelkerke 2002). Monitoring without being able to distinguish survival and dispersal can fail to reveal a serious problem until it’s too late to recover the population (Howe et al. 1991, Pulliam and Danielson 1991, Pulliam et al. 1992, Pulliam 1996). It is not possible to measure Florida Scrub-Jay survival and dispersal without colorbanding.

Additional descriptions of scrub, geography, and plant ecology specific to the Atlantic Coast are provided elsewhere (e.g., Schmalzer and Hinkle 1992 a, b; Schmalzer et al. 2001). Additional ecological relationships between Florida Scrub-Jays and habitat, specific to the Atlantic coast, are described elsewhere (Breininger and Schmalzer 1990; Breininger and Smith 1992; Breininger et al. 1991a, 1995, 1998). The Brevard County Natural Resources Department (2002) provides a history of Florida Scrub-Jay data collection on the mainland. Toland (2000) describes how conserving Scrub-Jays involves conserving open space and the quality of life.

A regional comprehensive plan specific to Florida Scrub-Jays has only been implemented in Indian River County (Smith Environmental Services 1999). The U.S. Fish and Wildlife funded Brevard County to develop a Habitat Conservation Plan a decade ago to conserve Florida Scrub-Jays and to minimize regulatory burdens (Swain et al. 1995). Although Brevard County chose not to implement a plan, it was regarded as an important case study internationally and was widely used by the U. S. Fish and Wildlife Service, many conservation acquisition organizations, and businesses for planning and project implementations (Noss et al. 1997). Because the plan was not implemented, the cost and uncertainties for thousands of individual projects is cascading upwards as competition for land that is not already developed increases and as recovery options decrease.

2.0 Objectives

The objectives of this empirical study were to:

h) quantify habitat and describe population structure,
i) provide data to prioritize mitigation and land acquisition strategies,
j) quantify habitat-specific demography (e.g., juvenile production, yearling production, breeder survival, helper survival)
k) quantify dispersal (site tenacity, pair bond fidelity, delayed breeding characteristics, dispersal distances, population exchanges among habitat fragments),
l) evaluate habitat quality identify habitat restoration and management needs,
m) quantify the colonization of restored and uninhabited habitat,
n) identify inventory criteria that identify habitat conditions where potential breeder production equals or exceeds breeder mortality.

Caption 2.0. Optimal scrub includes shrub-dominated landscapes that have many scrub oaks and open sandy areas with few trees.

3.0 Theoretical Approach

The methods used for mapping habitat potential and approaches for quantifying habitat specific demography rely on long-term studies by our colleagues at Archbold Biological Station and ourselves at Kennedy Space Center. Much of what was first known about Florida Scrub-Jay sociobiology resulted from >30 years of study in a large tract of optimal habitat at Archbold Biological Station (Woolfenden and Fitzpatrick 1984, 1991, 1996). Later studies revealed that patterns of sociobiology, demography, and dispersal varied greatly among and within landscapes (Breininger et al. 1995, 1996a, 1998; Thaxton and Hingtgen 1996, Stevens and Young 2002; Bowman unpublished).

Our approach greatly relies on studies that have shown that source-sink dynamics apply to Florida Scrub-Jay populations within individual landscapes (Mumme et al. 2000, Breininger and Oddy 2001, Breininger et al. 2003). Sources are net exporters of individuals and have births that exceed deaths; sinks are net importers and have deaths that exceed births (Pulliam 1988). Although source-sink dynamics usually consider population dynamics among subpopulations (Hanski 1999), they theoretically occur within complex, heterogeneous landscapes (Howe et al. 1991, Rodenhouse et al. 1997).

We use “territory quality transitions,” to compliment traditional ideas of source-sink dynamics (Breininger and Carter 2003). Traditional ideas focus on organisms physically moving from source to sink patches. However, shifting habitat quality and slight shifts in territory boundaries can cause individual territories to cycle between habitat quality states where reproduction exceeds mortality and where mortality exceeds reproductive success. We use “territory quality transitions” to describe the process of individual territories varying in quality temporally, which can allow optimal territories to “export” individuals to sinks without organisms actually relocating to territories. Because Florida Scrub-Jays routinely disperse from optimal territories into many types of sink territories, there is much potential to simply partition a landscape into potential territories and then determine the proportion of optimal territories needed to offset demographic losses in sinks. Our study focuses on quantifying the habitat-specific demographic data that is essential for applying source-sink theory (Pulliam et al. 1992). It is unrealistic for every territory to be optimal so that most managed landscapes probably will have a source-and-sink population structure.

There are limits to source-sink applications. For example, Florida Scrub-Jays do not always disperse into all types of marginal habitat (Woolfenden and Fitzpatrick 1984, Fitzpatrick and Woolfenden 1986). Furthermore source-sink ideas may collapse as one scales up to the metapopulation. For example, other investigators have reported that exchanges between conservation reserves and suburban territories tend to be one-way only: from suburbs to reserves (Thaxton and Hingtgen 1996; Bowman unpublished). Therefore empirical data is needed to quantify how Florida Scrub-Jays respond to habitat fragmentation. Landscape fragmentation by humans has many species biology effects that are described using ideas about metapopulation theory (Stith et al. 1996). But despite the eminence of metapopulation theory, there are little data and modeling has proceeded well ahead of empirical data (Doak and Mills 1994, Breininger et al. 2002). A number of metapopulation models might apply to Florida Scrub-Jay metapopulations (e.g., Kareiva 1990, McPeek and Holt 1992, Stith et al. 1996; Harrison and Taylor 1997, Stith 1999, Doncaster et al. 1997, Diffendorfer 1998).

Our approach focuses on how to maximize the viability within reserves because Florida Scrub-Jays have poor dispersal abilities so that maintaining subpopulation viability is probably the key to maintaining metapopulation viability (Drechsler and Wissel 1998). Populations in many landscapes are too small to withstand environmental stochasticity, catastrophes, inbreeding, and changing environments so that patches must be linked. Most Florida Scrub-Jay populations will probably not persist because they occur in urban and suburban landscapes (Stith et al. 1996, Breininger 1999, Stith 1999, Bowman unpublished). Many large expanses of scrub are unoccupied or are below carrying capacity because of the reduction in the fire regime (Swain et al. 1995, Stith 1999). These large scrub landscapes have the greatest probabilities for population persistence if restored and re-colonized (Stith 1999). Florida Scrub-Jays that reside in suburbs are possible colonists into restored areas (Breininger et al. 1999a, Breininger 1999, Bowman unpublished). However males have lower dispersal tendencies and seldom move among habitat fragments (Breininger 1999). Generally, empirical studies focus on situations where animals settle and live at moderate or high population densities so that little is known about habitat selection when habitats are unsaturated (Greene and Stamps 2001). Habitat quality and many of the common ideas about habitat selection might be poor predictors of dispersal into restored areas that are far below carrying capacity (Greene and Stamps 2001). Therefore, we not only investigate demographic responses to habitat restoration but we also investigate recolonization and dispersal among subpopulations that vary in size, arrangement, and quality.

This study began in Brevard County until we discovered large expanses of occupied habitat in Indian River County that had not been previously identified. These areas were purchased as part of the St. Sebastian River State Buffer Reserve (Sebastian Buffer Reserve). We expanded our studies into Indian River County because it became clear that a significant portion of the metapopulation overlapped with Indian River County. The Sebastian Area-Wide Florida Scrub-Jay Habitat Conservation Plan (Sebastian HCP) provided additional information in Indian River County (Smith Environmental Services 1999). Much information summarized in the Sebastian HCP resulted from previous colorbanding studies by Toland (unpublished).

This reported is organized into three major sections. The first describes habitat and population structure. The second focuses on the demography and dispersal of color-banded Florida Scrub-Jays residing in mainland metapopulations. A minor section updates a previous study of an isolated metapopulation on Brevard’s outer barrier island (Breininger 1999). The final major section addresses recovery and management. A literature cited section ends the report.

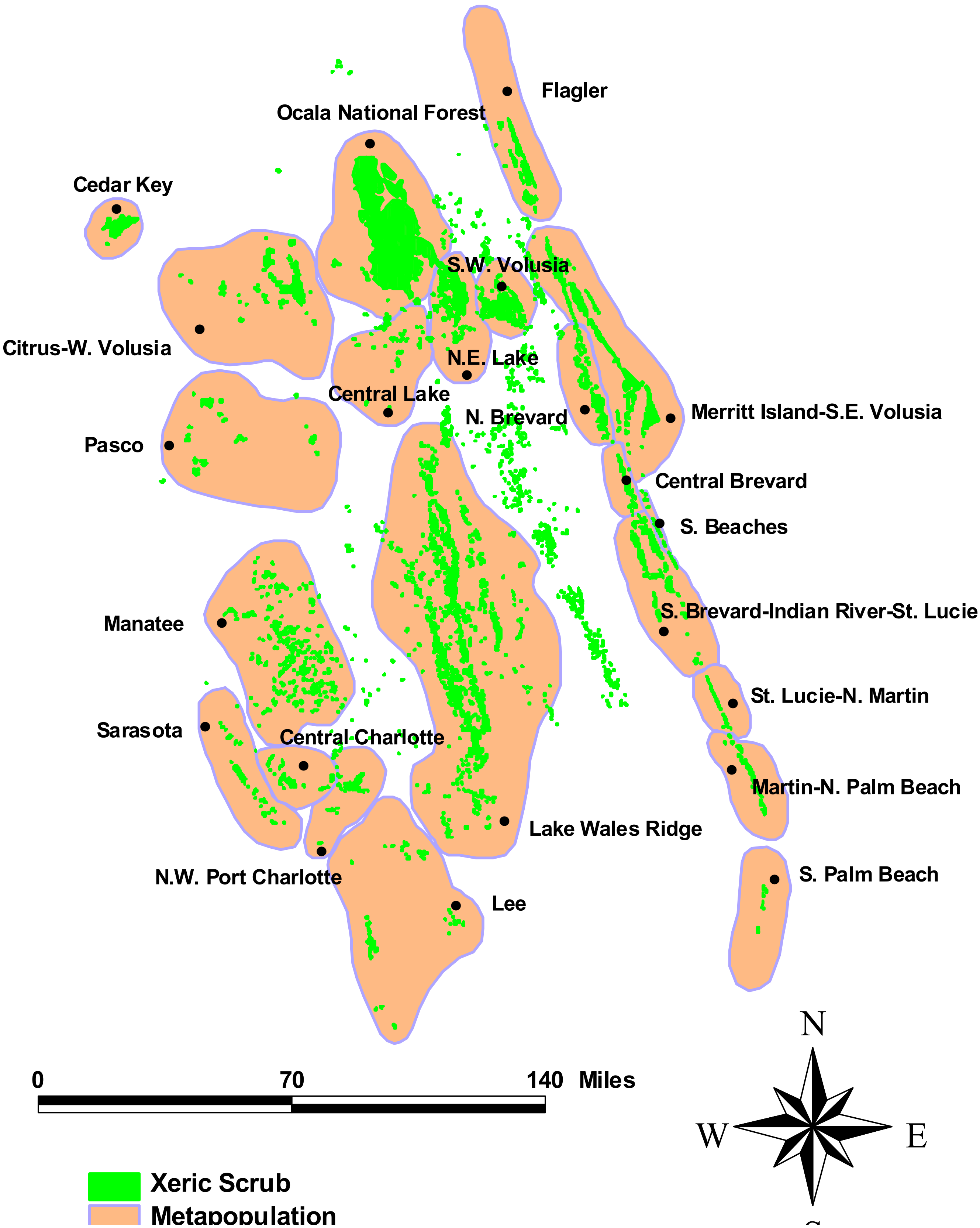
Caption 3. Florida Scrub-Jays near the time of fledging.

4.0 Habitat and Population Status of the Florida Scrub-Jay along Central Florida's Atlantic Coast.

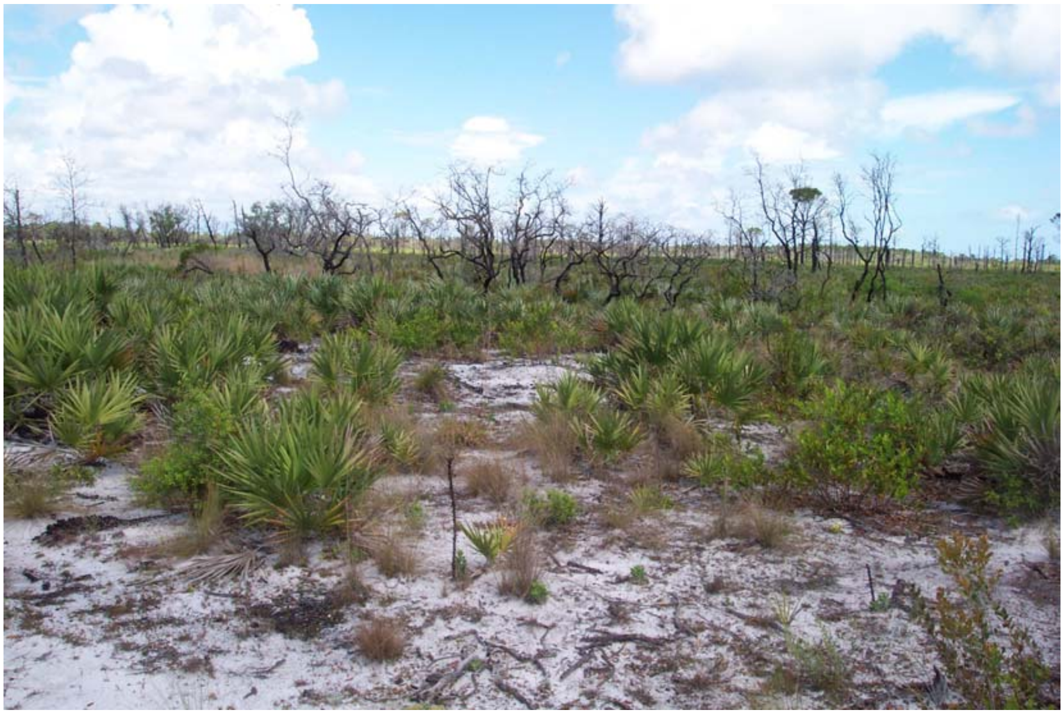
The study focuses on metapopulations on Florida's mainland that occur in Brevard County and Indian River County (Figure 1). These include the North Brevard, Central Brevard, and South Brevard-Indian River-N. St. Lucie metapopulation (Stith 1999). The North Brevard metapopulation is the 7th largest metapopulation in the range and Central Brevard is the 10th largest. The South Brevard-Indian River-N. St. Lucie metapopulation is the 4th largest metapopulation in the range and the largest on the mainland of the Atlantic Coast.

The nearby Merritt Island-S.E. Volusia metapopulation is the largest along the Atlantic coast and occurs mostly on the barrier islands (Merritt Island and Cape Canaveral). Nearly all of this population occurs on Kennedy Space Center and Cape Canaveral Air Force Station. Congress established that primary purpose of these properties was to support the nation's space and military programs. Lands not directly being used by these programs are managed as Merritt Island National Wildlife Refuge and Canaveral National Seashore. Mechanisms exist to remove habitat from conservation when necessary to support the primary purpose of these properties. The commercialization of the space program has also led to a proposed investment by the State of Florida to extensively develop this area as the Nation's spaceport (http://www.yourspaceport.com/). The low topography of the barrier island populations and proximity to the Atlantic Ocean makes them vulnerable to hurricanes and changes in sea level (Breininger et al. 1996b, 1999a). Consequently, conservation cannot only rely on the federal properties to conserve Florida Scrub-Jay populations in east central Florida.

Figure 1. Florida Scrub-Jay Metapopulations (Stith 1999).



Caption 4. Extensively burned short scrub a few months after fire. These areas are temporarily unoccupied or are population sinks before becoming optimal.



It is has almost always been assumed that Florida Scrub-Jay populations are restricted to xeric oak scrub on well-drained soils (Woolfenden and Fitzpatrick 1984, 1991, 1996) and so conservation focuses almost entirely on this habitat (e.g., Swain et al. 1995, Stith et al. 1996, Root 1998, Stith 1999). Florida Scrub-Jays on Merritt Island often occur in pine flatwoods on poorly-drained soils (Breininger et al. 1991aa, 1995), and long-term studies identified that these Florida Scrub-Jays can have reproductive success that exceed mortality depending on the arrangements of shrub height (Breininger and Oddy 2001). We mapped Florida Scrub-Jay habitat using new criteria because we found that existing scrub maps did not explain the existing distribution of Florida Scrub-Jays. We mapped scrub from Volusia County south to Wabasso on the Atlantic Coastal Ridge and State Route 60 on the Ten Mile Ridge. We then reevaluated metapopulation structure.

4.1 Methods

Habitat Mapping and Modeling. Habitats features needed to evaluate habitat suitability and their associated uncertainties are described in detail elsewhere (e.g., Duncan et al. 1995, Breininger et al. 1998, Burgman et al. 2001). Here, we map habitat quality in broader categories and at less resolution than our previous NASA studies because the geographical extent precluded detailed mapping and we wanted to develop and test procedures that were more practical for land managers and planners to implement. These approaches have been successfully used to describe source-sink dynamics on Merritt Island (Breininger and Oddy 2001, Breininger and Carter 2003).

We obtained high resolution (1 meter) digital orthophoto quads (DOQs) for 1994 and 1999. The DOQs are available across the species range and provide consistent, convenient, high quality templates for managing and displaying spatial data using readily available software (e.g., ArcView) on most hardware and software platforms. Using the DOQs as templates provides a mechanism to view thematic layers with digital photography as a background and facilitates the development of techniques that can be used at scrub sites. All habitat maps were registered to DOQs. All Geographical Information Analyses (GIS) procedures used ARC/INFO files, and none were performed at survey level accuracy. Boundaries between different features were usually mapped within 1-10 meters of the actual location but could occasionally be 30 meters from the actual boundary. Our target minimum mapping unit was 0.4 ha (1 acre) but we often distinguished smaller features that were readily identified. We also viewed imagery from 1943 to evaluate habitat potential. Habitat potential was important to consider because many of today's forests were scrub and flatwoods that could be restored (Duncan et al. 1999). Historical aerial photography is also available across the species range.

Our ARC/INFO coverage's included the following attributes: (1) habitat type, (2) tree cover, (3) height, and (4) presence/absence of openings among scrub oaks. Habitat types included: scrub, ruderal grass, marsh, permanent forest, disturbed grass/shrubland, water, human cultural features, and unsuitable pasture (Table 1). Scrub included: oak scrub (> 50 % scrub oak cover), palmetto-oak scrub (5 – 49 % scrub oak cover), and palmetto scrub (< 5 % scrub oak cover; Table 2). Permanent forest included pine and hardwood forests that were present in 1943 or scrub that became forest and existed as disjunct landscape areas that did not justify restoration to scrub. Forests within disjunct landscapes comprised sites that probably would not be within a Scrub-Jay reserve and areas that probably would not be important to connect reserves. Forested scrub, which became forest by 1994 because of fire suppression and habitat fragmentation, could become suitable to Florida Scrub-Jays after restoration. Forested scrub was classified as scrub and not forest in the habitat layer and included areas with pine and oak canopies. Tree density classes included: savanna (< 15 % tree cover), woodland (15 - 65% tree cover), and forest (> 65% tree cover). Height mapping classes (Table 3) included: (1) short scrub (< 120 cm tall), (2) a mosaic of short (< 120 cm tall) and optimal scrub (120 - 170 cm tall), and (3) tall scrub (> 170 cm tall) which could have included all tall scrub and mixture of tall scrub and other height classes.

For 1994 habitat conditions, we aggregated scrub into potential reserve units (PRUs) comparable to "critical habitat polygons" used by Stith (1999) by excluding habitat fragments categorized as "suburban territories". PRUs were areas of oak or palmetto-oak that were contiguous or connected by mesic flatwoods or swale marshes that were large enough to support >1 Florida Scrub-Jay territory. We overlaid PRU boundaries on 1999 DOQs to digitize habitat destroyed by humans. We used the area of oak and palmetto-oak destroyed by humans between 1994 and 1999 to estimate the rate of habitat loss within PRUs.

Table 1. Definitions of habitat mapping categories.

Habitat type	Description
Scrub	Oak scrub and palmetto-lyonia with or without a interlocking tree canopy; potentially suitable Scrub-Jay habitat that includes areas forested today but were scrub in the 1943 landscape.
Ruderal grass	Bahia grass or open sandy areas with sparse vegetation <15 cm tall.
Marsh	Wetlands dominated by herbaceous vegetation.
Forest	Dense tree canopy not restorable to Scrub-Jay habitat; hammocks, swamps, and scrub with a dense tree canopy that are not adjacent to a potential reserve; native hammocks and swamps.
Disturbed grass/shrubland	Human disturbed areas with shrubs and grass such as pasture land that could be suitable.
Water	Lakes, ponds, and lagoon waters.
Human cultural features	Roads, buildings, and surrounding ruderal grass.
Unsuitable pasture	Pasture with no shrubs; trees sometimes present.

Table 2. Definitions of Florida Scrub-Jay habitat quality features within scrub polygons.

Feature	Description	Habitat Quality
Oak cover:		
Oak scrub	Scrub with > 50 % oak cover.	Optimal
Palmetto-oak	Palmetto-lyonia with 5 – 49 % oak cover.	Suboptimal
Palmetto	Palmetto-lyonia without oaks (< 5% oak cover).	Suboptimal
Open space:		
Present	Mosaic of open sandy areas among oaks.	Optimal
Absent	Continuous shrubs or dense grass > 15 cm tall	Suboptimal
Tree cover:		
Savanna	0 – 15 % tree canopy cover.	Optimal
Woodland	16 – 65 % tree canopy cover.	Suboptimal
Forest	> 65 % tree canopy cover.	Suboptimal
Height categories:		
Short	Large areas (> 10 ha) completely burned (< 120 cm tall) within the last 3 - 5 years.	Suboptimal
Optimal mosaic	Patches of scrub oaks at optimal height (120 – 170 cm) without patches of tall scrub (> 170 cm) greater than 0.4 ha.	Optimal
Tall	Tall scrub or a mosaic of other height categories that include tall scrub patches > 0.4 ha.	Suboptimal

Note: Tall scrub was distinguished into all tall and tall mix within territories that were subject to detailed demographic investigations.

Caption 5. Restored, occupied, optimal scrub that was an unoccupied sand pine forest 5 years previously because of fire suppression.

We became concerned that the areal extent of mapped features might not identify how Florida Scrub-Jays partition a landscape so that we created a potential territory model for the population. Territory boundaries rarely coincide with habitat features, except along open water (Breininger et al. 1995, 1998). This is a particular problem for Florida Scrub-Jays in coastal areas because habitat features are associated with geological process that formed long narrow ridges and swales (Breininger et al. 1991a). Florida Scrub-Jay territories are not long and linear and often cross several ridges and swales (Breininger et al. 1995). Although fires are influenced by vegetation type, fires also generally cross dozens of ridges and swales so that habitat quality variation is also more complex than evident from simple vegetation maps (Breininger et al. 2002). To represent potential population structure, we subdivided the Brevard County and Indian River County into a grid where each cell approximated the size of a territory. We then classified the habitat potential of each grid cell as a binary attribute based on whether or not it was likely to represent the approximate location of a territory in a landscape.

We restricted the potential number territories within a PRU to number expected based on the areal extent of oak and palmetto-oak divided by 10 ha, which we called MIN POP SIZE. For each PRU we began classifying the potential of a grid cell by coding cells as potential territories based on whether the intersected well-drained oak scrub. We used U.S. Department of Agriculture soils maps (Huckle et al. 1974, Wettstein et al. 1984) to define well-drained soils. We added an attribute that defined potential territories as primary, secondary, and tertiary based on scrub oak cover (Breininger and Oddy 2001). We identified primary territories as those that intersected xeric oak scrub (see Breininger and Oddy 2001). We then coded additional cells as potential territories based on whether they intersected oak scrub polygons that were at least 0.4 ha in size but did not occur on well-drained soils; we termed these secondary territories (see Breininger and Oddy 2001). We then identified tertiary territories by finding grids cells that had the most scrub oak cover (excluding primary or secondary territories already identified), until the total number of potential primary, secondary, and tertiary territories equaled MIN POP SIZE. We differentiated secondary and tertiary territories in the potential territory model and not the habitat map because it is difficult to map small patches of oak scrub (< 0.4 ha). It is much easier to classify a grid cell based on particular habitat attributes (i.e. the presence of $\geq$ 0.4 ha of scrub with $\geq$50% scrub oak cover) than to explicitly map scrub oak patches of varying size and scrub oak cover.

Related studies indicate that most primary and secondary territories are occupied when fires are frequent (Breininger and Oddy 2001, Breininger and Carter 2001). Occupancy of potential tertiary territories is usually low (Breininger et al. 1991a) although numbers can fluctuate greatly if there is high immigration (Breininger and Oddy 2001). PRUs might have been able to support more tertiary territories resulting in a larger potential population size than we modeled but occupation of many more additional tertiary territories than we modeled would probably occur only upon the most favorable circumstances. We intend to explore these possibilities further using spatially explicit population models. Florida Scrub-Jay territories also occurred outside the PRUs, especially in Palm Pay and Port St John. We identified cells outside of PRUs as potential territories if they were occupied. We assumed that the 2001-2002 number of suburban territories was the maximum likely and that population would never exceed this upper limit because of rapid urbanization and a long history of fire exclusion.

We also classified potential territories into three categories based on their context to human-dominated landscapes because of potential edge effects (Mumme et al. 2000, Bowman and Woolfenden 2001). “Core” territories were not adjacent to human housing or hard surface roads. “Reserve Edge” territories were within potential reserves and bordered human landscapes, but were not adjacent to hard surface roads. “Suburban territories” occurred within suburban areas or were adjacent to hard surface roads.

To incorporate fire history, we classified potential territories based on their habitat suitability related to tree cover (Table 2) and shrub height (Table 3). The shrub height criteria have been useful for quantifying source-sink dynamics and the progress of restoration (Breininger and Carter 2003). We classified potential territories as protected, proposed but not protected, and unprotected by overlaying grid cells on thematic layers from EELs, Florida Department of Environmental Protection, and The Florida Greenways project.

Table 3. Height classes of potential Florida Scrub-Jay territories.

Height class	Description	Minimum mapping units
Short.	Entire territory was < 120 cm tall.	No patch taller than 120 cm was > 0.13 ha.
Short/optimal mix.	Territory was a mix of short and optimal scrub (120 - 170 cm tall) and had no tall scrub (> 170 cm tall).	At least 1 patch of optimal scrub was > 0.13 ha and at least 1 patch of short scrub was > 0.4 ha. No patch of tall scrub was > 0.4 ha.
Tall mix.	Territory was mix of tall scrub and short and/or optimal scrub.	At least 1 patch of tall scrub was > 0.4 ha. At least 1 patch of short or optimal scrub was > 0.4 ha acre.
Tall.	Entire territory was > 170 cm tall.	No scrub < 170 cm tall was > 0.4 ha.

Adapted from Breininger and Carter (2003).

Florida Scrub-Jay population surveys and analyses. We regularly surveyed areas within the 1992 polygons (Stith et al. 1996) and other known locations of jays to identify dispersals of colorbanded jays from the regularly censused demographic study areas (Chapter 5.0). In South Brevard County, surveys additional to the demographic study tracts were performed at least 1x per year since 1998. In other areas of Brevard County, these surveys were performed at least 1x per year between 2000 and 2002. Indian River County initiated a Sebastian Area-Wide Habitat Conservation Plan (Sebastian HCP) that provided habitat studies and Florida Scrub-Jay surveys (Smith Environmental Services 1999). Much of the demography data used to prepare the Sebastian HCP resulted from almost a decade of colorbanding by Toland (unpublished). Brevard County Natural Resource Management Office (2002) began new surveys to update the Scrub-Jay database. We also exchanged data with many environmental consultants and agency personnel. These exchanges provide additional opportunities to find new jay locations and dispersals given that large numbers of environmental assessments are being performed. The few areas not surveyed included some areas north of the Buck Lake Conservation Area, scrub west of Fox Lake, scrub north of the Micco Scrub Reserve, the Atlantic Coastal Ridge south of the Wabasso Scrub Sanctuary and the Ten Mile Ridge south of Sebastian Buffer Reserve. We estimated that the areas surveyed during 2000-2002 approached 85% of the potential territories.

We compared 1992 data (Swain et al. 1995, Stith et al. 1996, Root 1998) with 2002 data within areas that we described as “potential territory clusters” rather than the 1992 polygons because habitats changed since 1992 and the 1992 polygons did not represent any defined population structure. We described potential territory clusters as areas of contiguous suitable habitat occupied by Florida Scrub-Jays. The approach to define potential territory clusters began using the 1992 habitat polygons and subsequent locations of known territories and then extended outward into suitable habitat even if habitat occupancy was unknown. Suitable habitat included suitable oak and palmetto-oak scrub within open landscapes that lacked interlocking tree canopies. We assumed that suitable habitat was better for defining potential population structure than "occupied habitat" because it is difficult to define occupied habitat in fragmented landscapes during brief intervals of time (i.e., months) and because territory boundaries frequently change. Contiguity referred to suitable oak and palmetto oak patches not greater than 2 territory widths but connected by suitable matrix habitat. Suitable matrix included palmetto-lyonia, maintained grass, open sand, and marshes. These are often defended by Florida Scrub-Jays and occur within territory boundaries (Breininger et al. 1995, 1998). Potential territory clusters were generally comparable to polygons used to identify territories during the 1992 surveys (Swain et al. 1995, Stith et al. 1996, Root 1998) except that many previous polygons were combined because of their close proximity. We performed most of the 1992 surveys and knew that their boundaries did not represent population structure but represented boundaries associated with sampling logistics.

To describe potential subpopulation and population structure, we used 3 conservation protection scenarios that ranged from most favorable to least favorable. The middle scenario that probably best represented existing structure was produced by buffering territory cluster boundaries by 2.9 km to define separate subpopulations (Stith et al. 1996). We used a 6.0 km buffer from territory cluster boundaries to identify potential metapopulations (Stith et al. 1996). This slightly differs from Stith et al. (1996) because we did not use actual territory approximations. We argue, however, that territories are not stable because of habitat and population dynamics and it is difficult to define exact territory boundaries in areas below carrying capacity. The most favorable scenario used the same buffers to define subpopulations and metapopulations except that buffers were applied to PRUs and not territory clusters. This scenario assumed that most PRUs would be protected and restored and that jays would have re-colonized several fragments that were no longer occupied. The least favorable assumed that the only PRUs that would be protected would be those that already have some habitat already acquired for conservation. It also assumes that all remaining habitat would be destroyed because of current rapid urbanization. We believed all scenarios were plausible.

Caption 6. View from the Atlantic Coastal Ridge at Valkaria looking west into a large contiguously occupied landscape that was unoccupied 7 years ago before it was burned by a wild fire

4.2 Results

Habitat Characteristics and Potential Reserve Units Potential habitat was more contiguous when palmetto-oak was recognized as habitat (Figure 2). There were respectively 3541 ha and 4823 ha of xeric oak and palmetto oak scrub within reserves based on 1999 imagery. There were least 3686 ha of oak and palmetto-oak scrub outside PRUs in 1999. We estimated that 5% of the potential habitat within PRUs was destroyed between 1994 and 1999. Habitat loss rates probably increased since 1999 given that human population expansion rate increases in Brevard County have begun to exceed rapid growth rates in South Florida (Toland 2000, S. Kennedy pers. Comm.

Hereafter, we used potential territories from the grid cell model to describe habitat arrangements within PRUs (Table 4). The percentage of primary, secondary, and tertiary territories in the potential territory model respectively were 66%, 24%, and 10%. Approximately 35% of these potential territories had optimal tree cover (they were savannas); 42% had marginal tree cover (they were woodlands); and 23% of these were unsuitable (they were forests). Most forested territories were primary (Figure 3). The percentages of potential territories that were protected, proposed, and unprotected respectively were 31%, 24%, and 45%. Protected referred to territories purchased for conservation. Proposed referred to areas proposed for conservation by a land acquisition organization and not habitat polygons designated by Stith (1999) for Florida Scrub-Jay recovery. Proposed areas were also unprotected but unprotected territories here include areas where protection is not proposed by an organization that actually acquires land. Some unprotected areas included public lands (airports, golf courses, parks) that were public lands that did not have plans to permanently protect and manage their scrub. The greatest amount of proposed habitat was in North Brevard where land acquisition efforts had failed to reach agreement with private landowners. (Figure 4). Acquisition in Central Brevard has been limited by recent rapid urbanization that resulted in a high cost of land and excessive fragmentation that diminished its value for many types of organisms not restricted to scrub. Consequently, many once high ranked potential conservation areas have been withdrawn from Central Brevard. The South Brevard-Indian River-St. Lucie metapopulation had the greatest amount of protected habitat but much of it still remains unprotected. There were a large number of potential territories that were unprotected forests or woodlands and therefore were not occupied by Florida Scrub-Jays (Figure 5).

The North Brevard metapopulation had the greatest proportion of potential territories that were forest (Figure 6). The percentages of potential territories that were core, reserve edge, or suburban respectively were 40%, 21%, and 39%. Conservation land acquisition efforts have acquired a high proportion of core territories, where as many unprotected territories bordered roads (suburban; Figure 7). However, a large number of core and edge territories (potential) remained unprotected, especially in areas north of Buck Lake, South of Grant Road and north of the Micco Scrub Sanctuary, and south of St. Sebastian River State Buffer Reserve along the Ten Mile Ridge.

Caption 7. Optimal palmetto-oak.

Figure 2. Oak Scrub, Palmetto-Oak, and Metapopulation Boundaries on the Mainland of Central Florida's Atlantic Coast

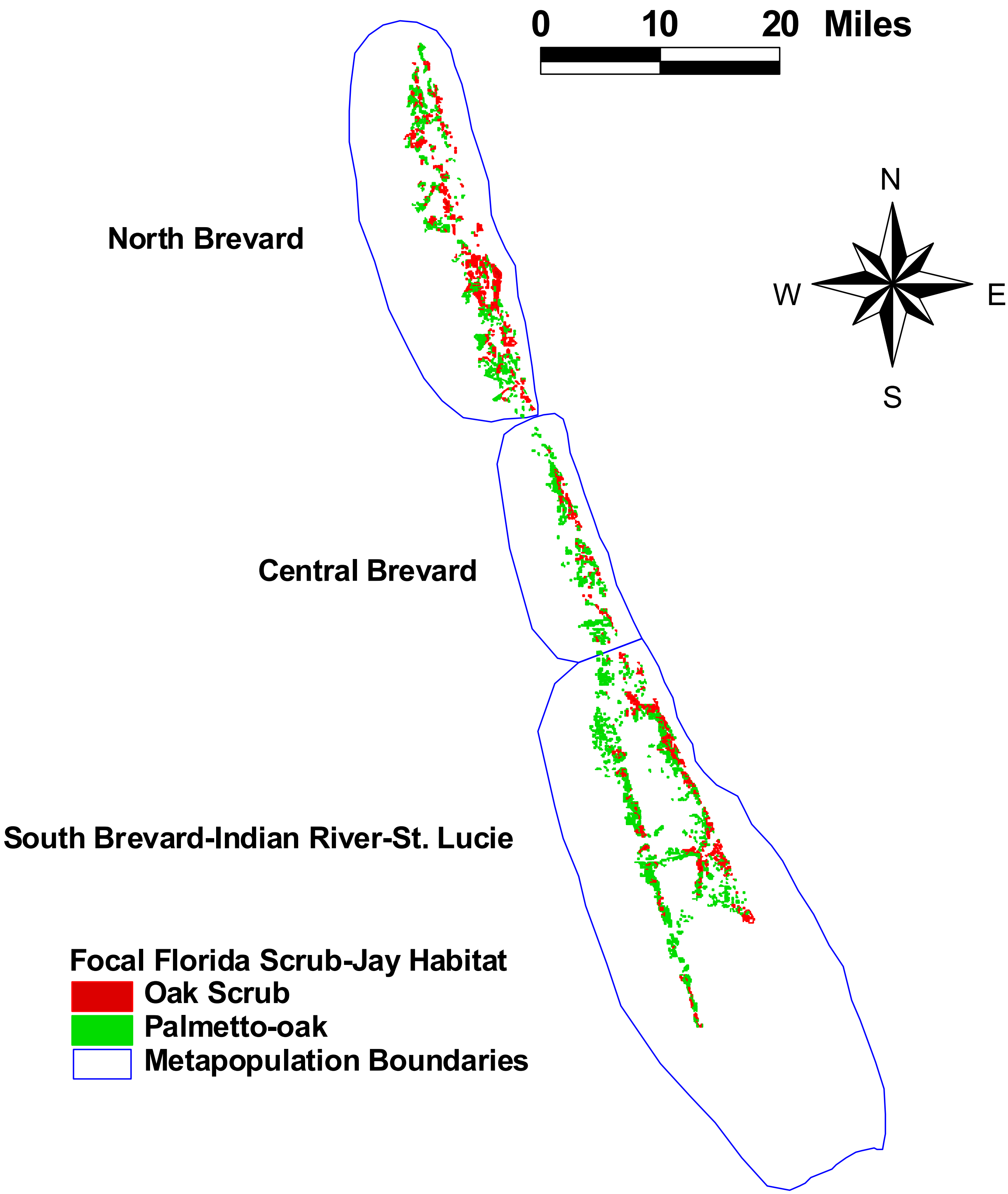


Table 4. Habitat Attributes of Territories in Potential Reserve Units (PRUs) [a.]

PRU	Potential Territories [b]	Protected [c]	Proposed [d]	Core [e]	Reserve Edge [f]	Suburb [g]	Optimal [h]	Unsuitable [i]
1	10	0	4	6	1	3	5	0
2	2	0	0	0	0	2	0	0
3	29	0	0	22	2	5	18	2
4	6	0	0	0	4	2	2	0
5	1	0	0	0	0	1	0	1
6	3	0	0	0	1	2	0	1
7	1	0	0	0	1	0	0	1
8	7	0	0	0	0	7	0	0
9	15	15	0	13	2	0	8	2
10	4	4	0	2	2	0	0	0
11	1	0	0	0	0	1	0	1
12	2	0	0	0	0	2	0	2
13	6	0	0	1	0	5	0	5
14	3	2	0	0	2	1	0	2
15	18	10	8	13	1	4	0	4
16	2	0	0	0	1	1	0	2
17	5	0	0	1	0	4	0	5
18	20	0	20	14	0	6	0	2
19	5	0	0	0	1	4	0	5
20	14	2	12	1	9	4	0	4
21	19	5	10	2	7	10	0	12
22	14	0	14	4	0	10	0	2
23	2	0	1	0	0	2	0	0
24	53	2	35	12	16	25	0	22
25	1	0	0	0	0	1	0	1
26	2	0	0	0	0	2	0	2
27	3	0	0	0	0	3	0	3
28	2	0	0	0	0	2	0	0
29	35	5	22	5	8	22	4	5
30	4	0	0	0	1	3	0	1
31	19	0	0	6	6	7	0	1
32	7	0	0	2	0	5	0	7
33	3	0	0	0	1	2	0	2
34	2	0	0	0	2	0	0	0
35	2	0	0	0	1	1	0	1

PRU	Potential Territories [b]	Protected [c]	Proposed [d]	Core [e]	Reserve Edge [f]	Suburb [g]	Optimal [h]	Unsuitable [i]
36	39	15	20	10	18	11	15	7
37	4	0	0	0	3	1	2	0
38	1	0	0	0	0	1	0	1
39	1	0	0	0	0	1	0	0
40	5	0	0	0	2	3	1	2
41	3	0	0	1	2	0	0	0
42	1	0	0	0	0	1	0	0
43	2	0	0	0	2	0	0	0
44	1	0	0	0	0	1	0	0
45	2	0	0	0	0	2	0	0
46	2	0	0	0	0	2	0	2
47	8	0	0	2	2	4	0	1
48	2	0	0	0	0	2	1	0
49	2	0	0	0	0	2	0	0
50	1	0	0	0	0	1	0	0
51	2	0	0	0	0	2	0	0
52	10	0	0	1	9	0	2	0
53	2	0	0	0	2	0	0	0
54	2	0	0	0	1	1	2	0
55	2	0	0	0	2	0	0	1
56	3	0	0	0	0	3	0	0
57	5	0	0	0	0	5	0	4
58	1	1	0	0	0	1	0	1
59	1	0	0	0	0	1	0	1
60	2	0	0	0	0	2	0	2
61	5	0	0	0	0	5	0	0
62	10	0	0	3	1	6	2	0
63	2	0	0	0	0	2	0	0
64	30	15	5	5	17	8	0	22
65	28	10	14	18	8	2	2	8
66	1	0	0	0	0	1	1	0
67	1	0	0	0	1	0	0	0
68	39	16	7	17	15	7	12	6
69	5	1	4	2	2	1	1	1
70	9	0	8	5	2	2	2	1
71	1	0	0	0	1	0	0	1

PRU	Potential Territories [b]	Protected [c]	Proposed [d]	Core [e]	Reserve Edge [f]	Suburb [g]	Optimal [h]	Unsuitable [i]
72	1	0	0	0	0	1	0	1
73	23	2	21	19	4	0	7	1
74	1	0	0	0	0	1	0	0
75	2	0	0	0	0	2	0	0
76	1	0	0	0	0	1	0	0
77	3	0	0	1	0	2	0	3
78	2	2	0	2	0	0	0	0
79	35	33	0	26	0	9	13	1
80	11	0	0	0	6	5	0	3
81	6	6	0	3	0	3	0	2
82	1	0	0	1	0	0	0	0
83	11	11	0	7	0	4	2	1
84	9	9	0	8	0	1	2	3
85	39	39	0	39	0	0	0	8
86	13	6	0	2	7	4	2	3
87	44	44	0	43	0	1	20	1
88	1	0	0	0	0	1	0	1
89	3	0	0	0	2	1	0	3
90	2	0	0	0	1	1	0	0
91	2	2	0	0	0	2	0	1
92	30	7	0	20	0	10	3	0
93	1	0	0	0	0	1	0	0
94	1	1	0	1	0	0	1	0
95	6	4	0	1	3	2	3	1
96	1	0	0	0	0	1	0	0
97	1	0	0	0	0	1	0	0
98	4	0	0	0	0	4	0	0
99	14	0	0	1	1	12	0	1
100	2	0	0	0	0	2	0	0
101	2	0	0	0	1	1	0	1

Entries are the number of potential territories. [a] Landscapes having enough (>10 ha) scrub to support at least one Florida Scrub-Jay territory. [b] Estimated as the area of oak and palmetto-oak divided by the average territory size (10 ha). [c] Florida Department of Environmental Protection, Brevard County Environmentally Endangered Lands Program (EELs), or St. Johns River Water management District. [d] Proposed for conservation by EELs or the Florida Greenways proposal. [e] Number of potential territories not adjacent to roads or suburbs. [f] Number of potential territories adjacent suburbs. [g] Number of potential territories adjacent to roads suburbs. [h] Number of territories at optimal height. [i] Number of territories that were unsuitable because of interlocking tree canopies.

Figure 3. The number of potential territories (y-axis) in relation to tree and cover and oak cover. Savanna, woodland, and forest respectively had 0-15%, 16-65%, and >65% tree canopy cover. Primary territories had oak scrub on well-drained soils. Secondary and tertiary territories occurred entirely on poorly-drained soils. Secondary territories had patches of >50% scrub oak cover that were >0.4 ha.

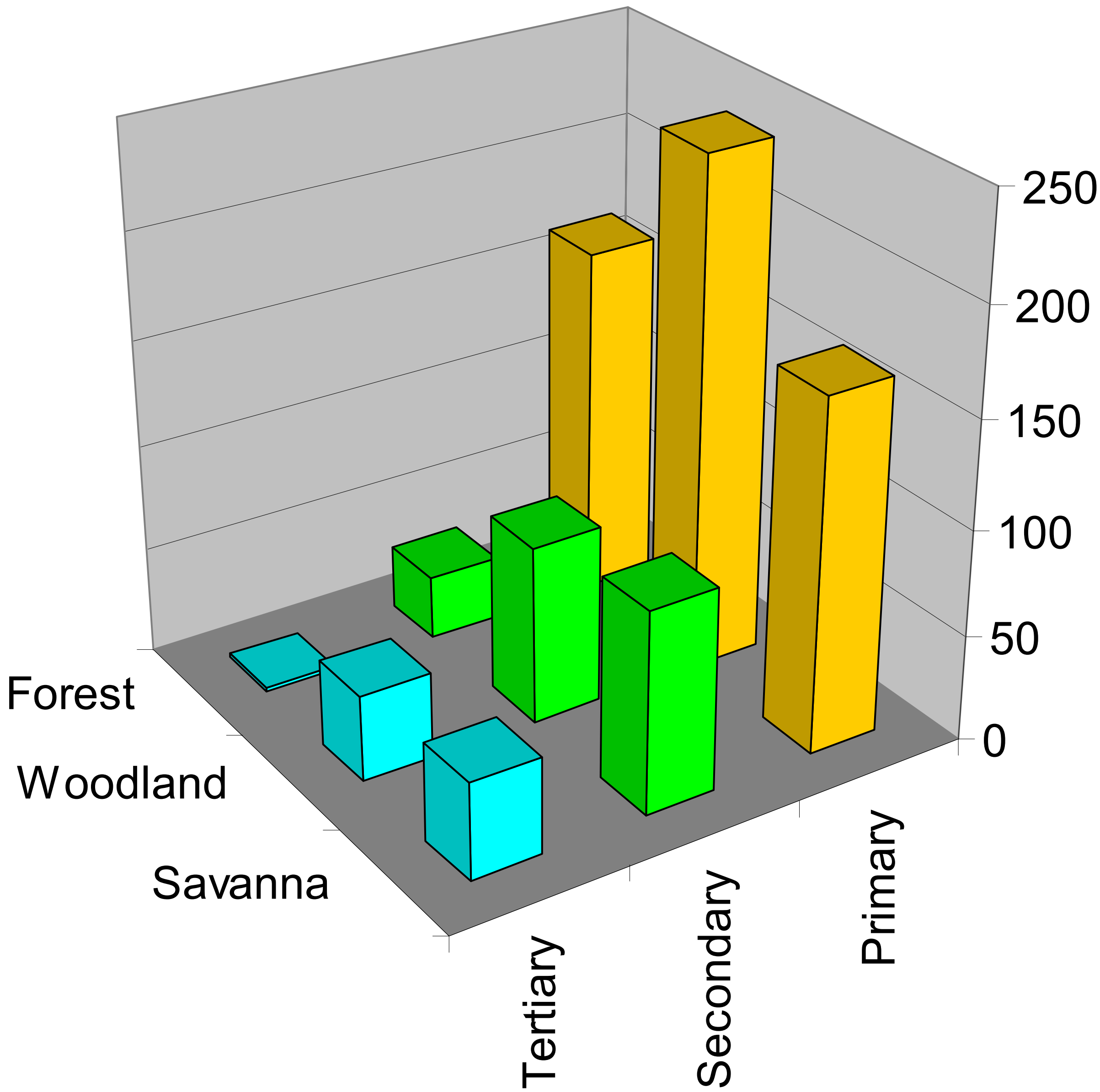
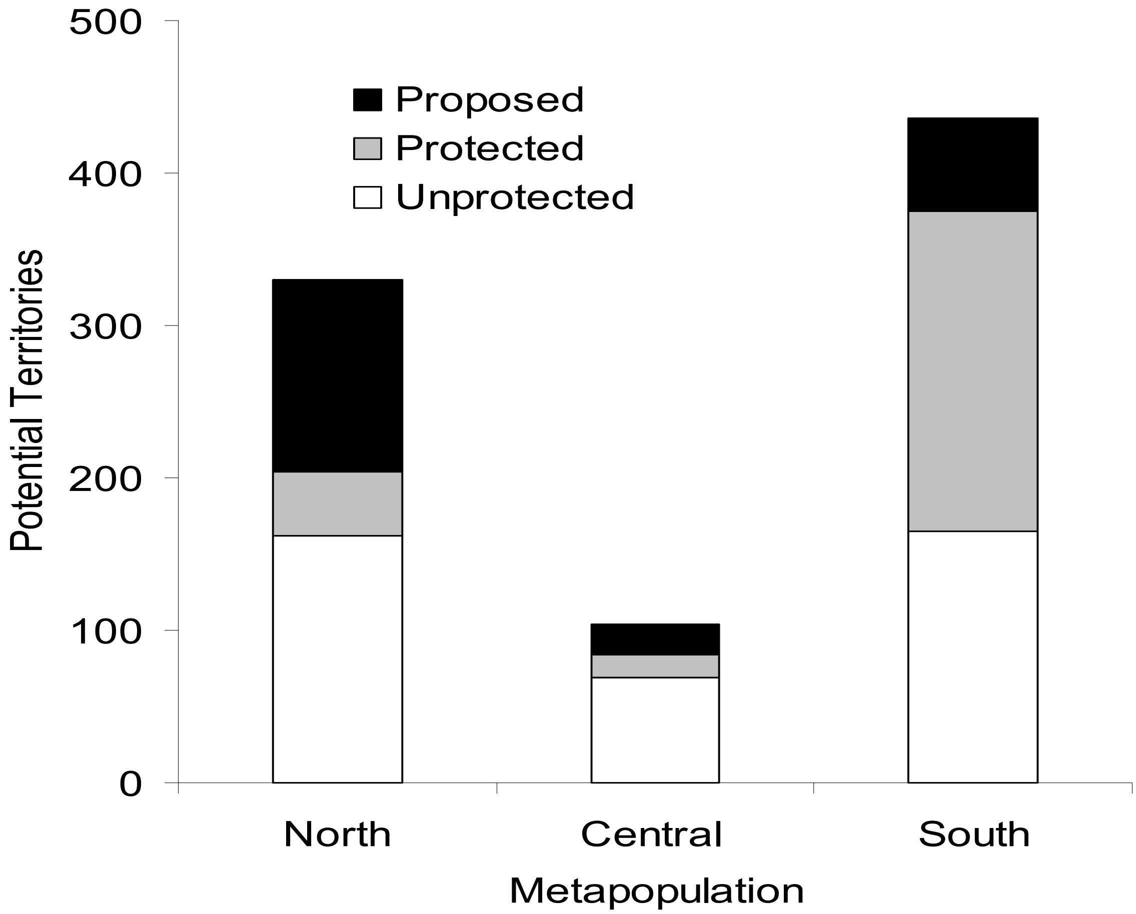


Figure 4. Number of potential territories by metapopulation and protected status. Protected territories occurred in areas purchased for conservation. Proposed territories were only proposed for acquisition. No acquisition has yet been proposed by conservation acquisition organizations for unprotected territories.



The percent of potential territories that were short, optimal, tall mix, or tall respectively were 3%, 16%, 44%, and 37%. Few suburban or reserve edge territories were optimal and most potential core territories were tall mix (suboptimal; Figure 8). Most potential territories in the North Brevard metapopulation were tall (Figure 9). Most protected territories were tall mix (Figure 10). Most unprotected territories were tall mix or tall. Most primary territories were tall, especially compared to secondary territories (Figure 11). Figure 12 provides PRUs overlaid on 1999 photography.

Territory Clusters. Five territory clusters occupied in 1992 were not occupied in 2001. The boundaries of PRUs and territory clusters did not directly overlap because many Florida Scrub-Jays occur in habitat fragments (e.g., Palm Bay) that were not within PRUs (Figure13). The delineation of clusters relied on suitable oak and palmetto-oak, whereas the PRUs boundaries relied on all oak and palmetto-oak. Figure 14 provides potential territory clusters overlaid on 1999 photography.

Caption 8. Malabar was an open savanna (A: 1943) that became forest and overgrown scrub with few openings (B: 1994), except along man-made edges.

Figure 5. The number of potential territories (y-axis) in relation to tree cover and protected status. Savanna, woodland, and forest respectively had 0-15%, 16-65%, and >65% tree canopy cover. Protected territories occurred in areas purchased for conservation. Proposed territories were only proposed for acquisition. No acquisition has yet been proposed by conservation acquisition organizations for unprotected territories.

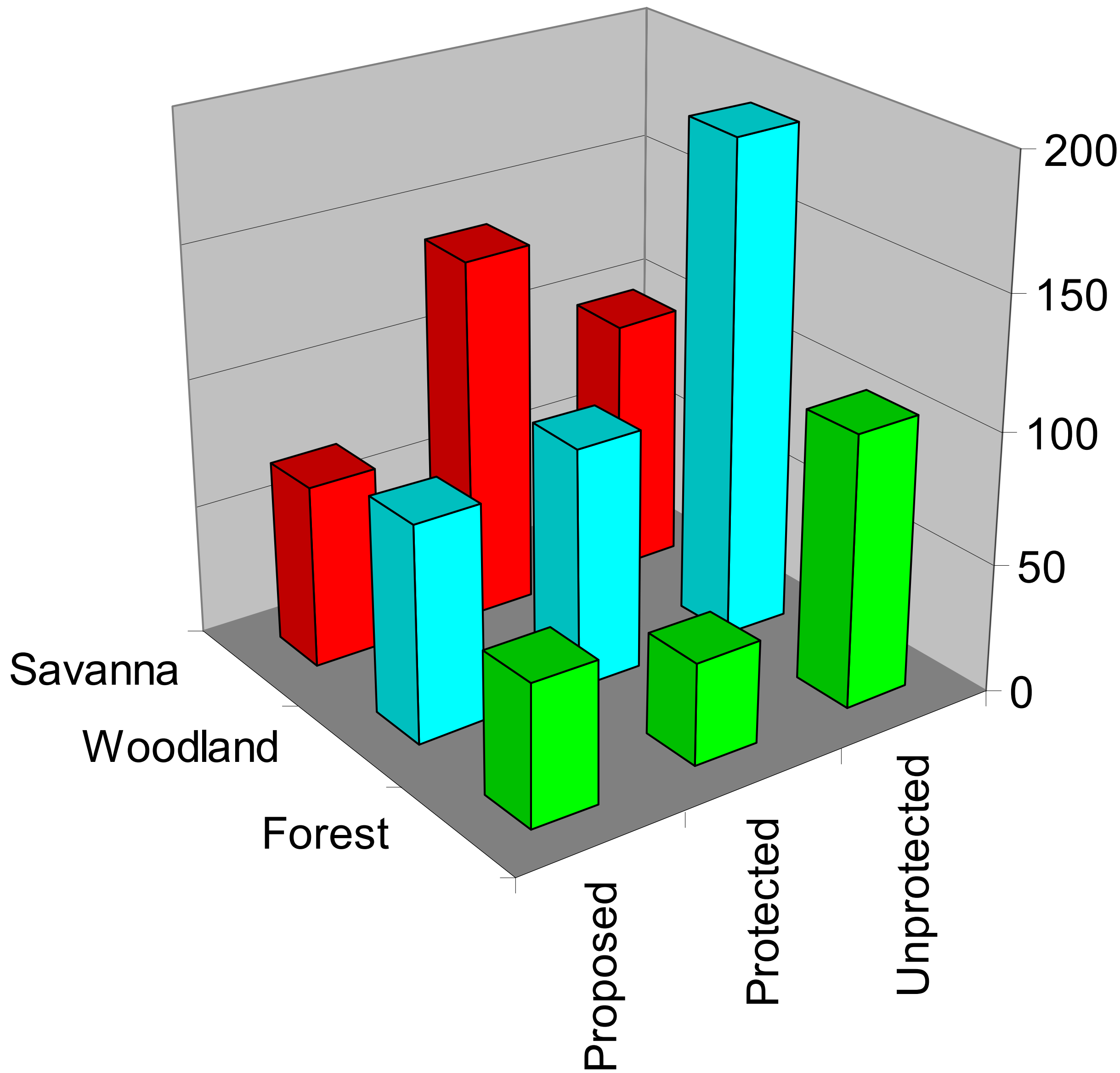


Figure 6. The number of potential territories (y-axis) in relation to metapopulation and tree cover. Savanna, woodland, and forest respectively had 0-15%, 16-65%, and >65% tree canopy cover.

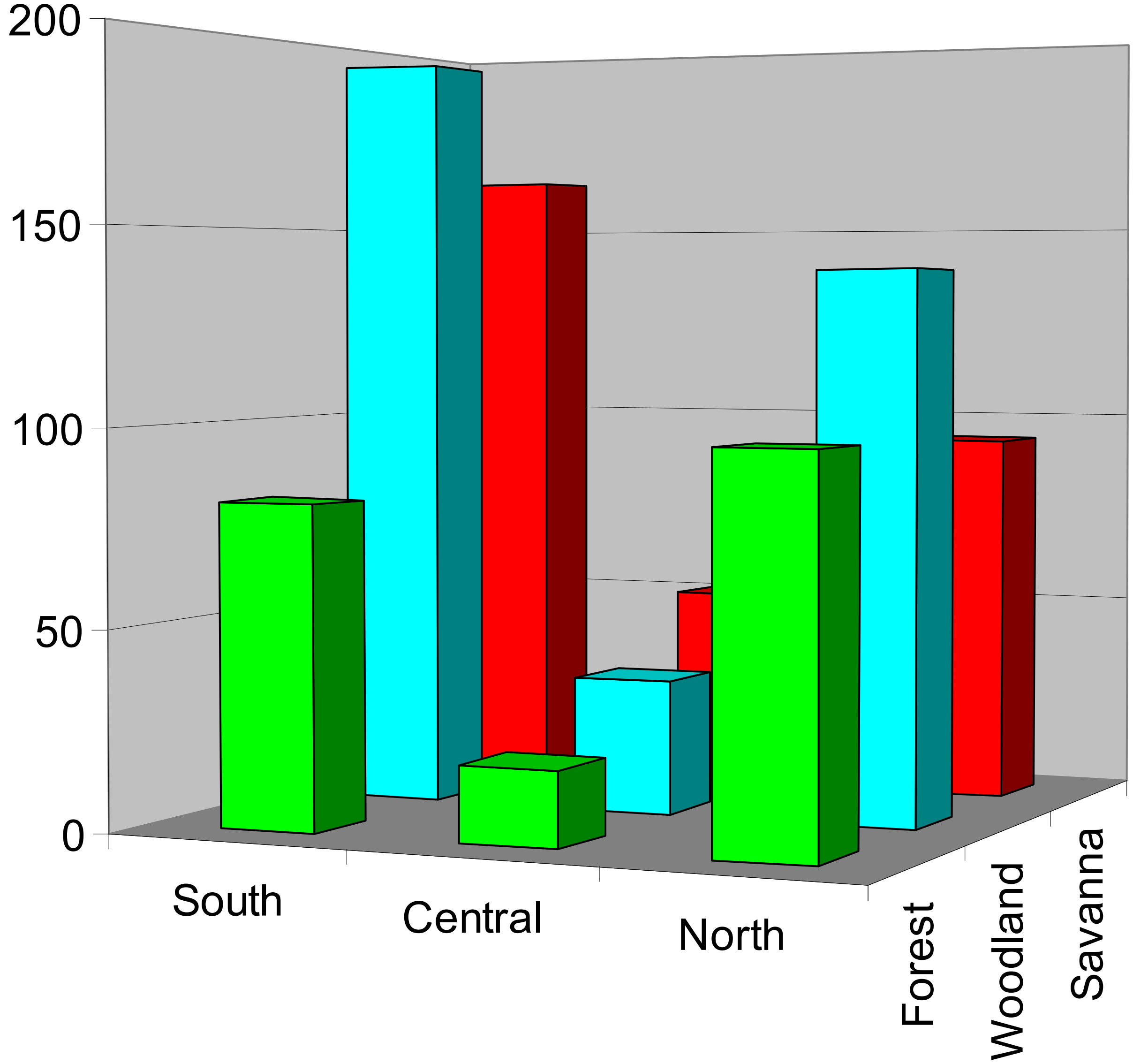


Figure 7. The number of potential territories (y-axis) in relation to protected status and edge. Protected territories occurred in areas purchased for conservation. Proposed territories were only proposed for acquisition. No acquisition has yet been proposed by conservation acquisition organizations for unprotected territories. Core territories were surrounded by other potential territories, pine flatwoods, marshes or other natural communities. Edge territories bordered human landscapes but not roads where traffic exceeded 35 mph. Suburban territories bordered busy roads.

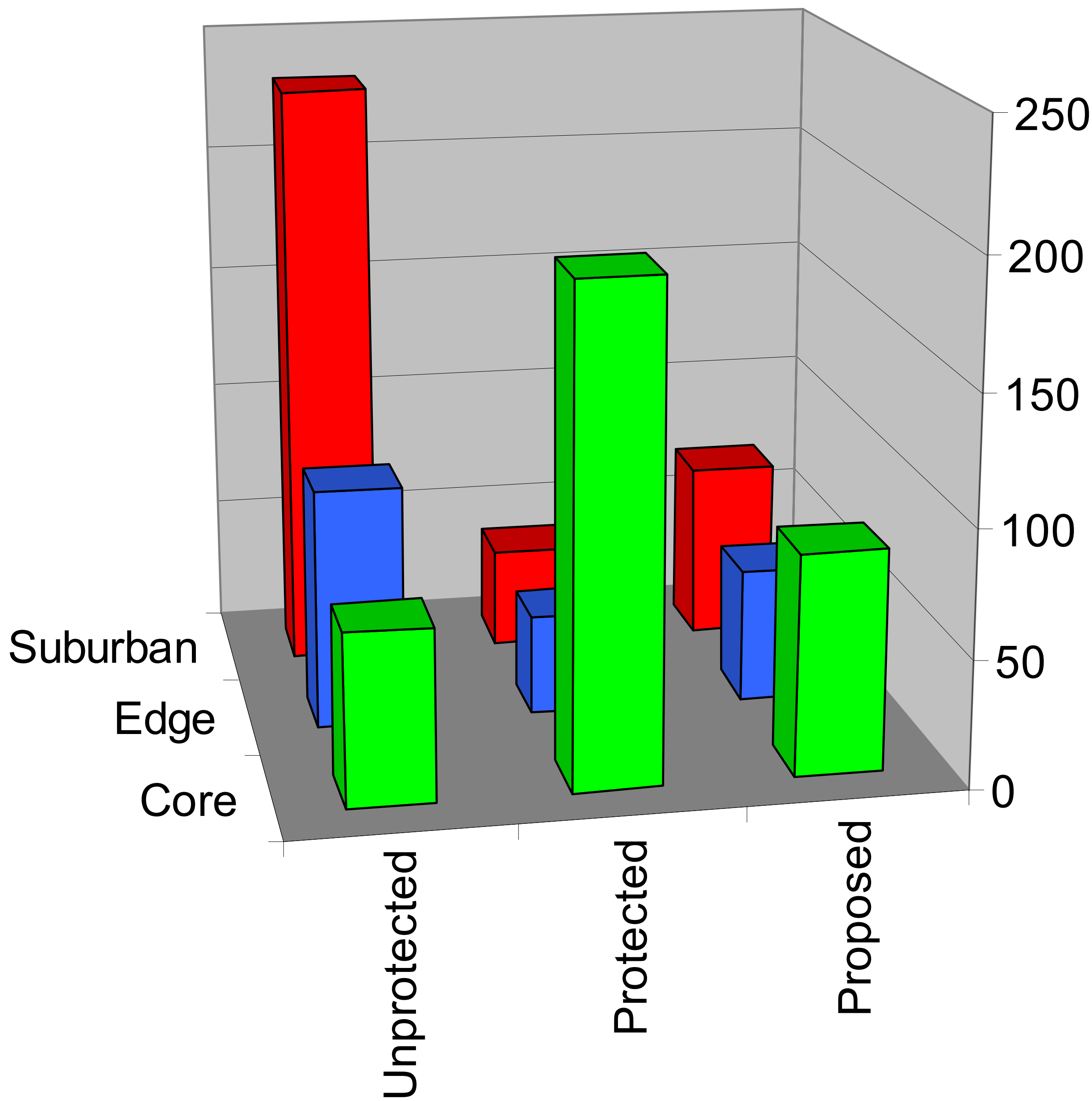


Figure 8. The number of potential territories (y-axis) in relation to edge and scrub height arrangement. Core territories were surrounded by other potential territories, pine flatwoods, marshes or other natural communities. Edge territories bordered human landscapes but not roads where traffic exceeded 35 mph. Suburban territories bordered busy roads.

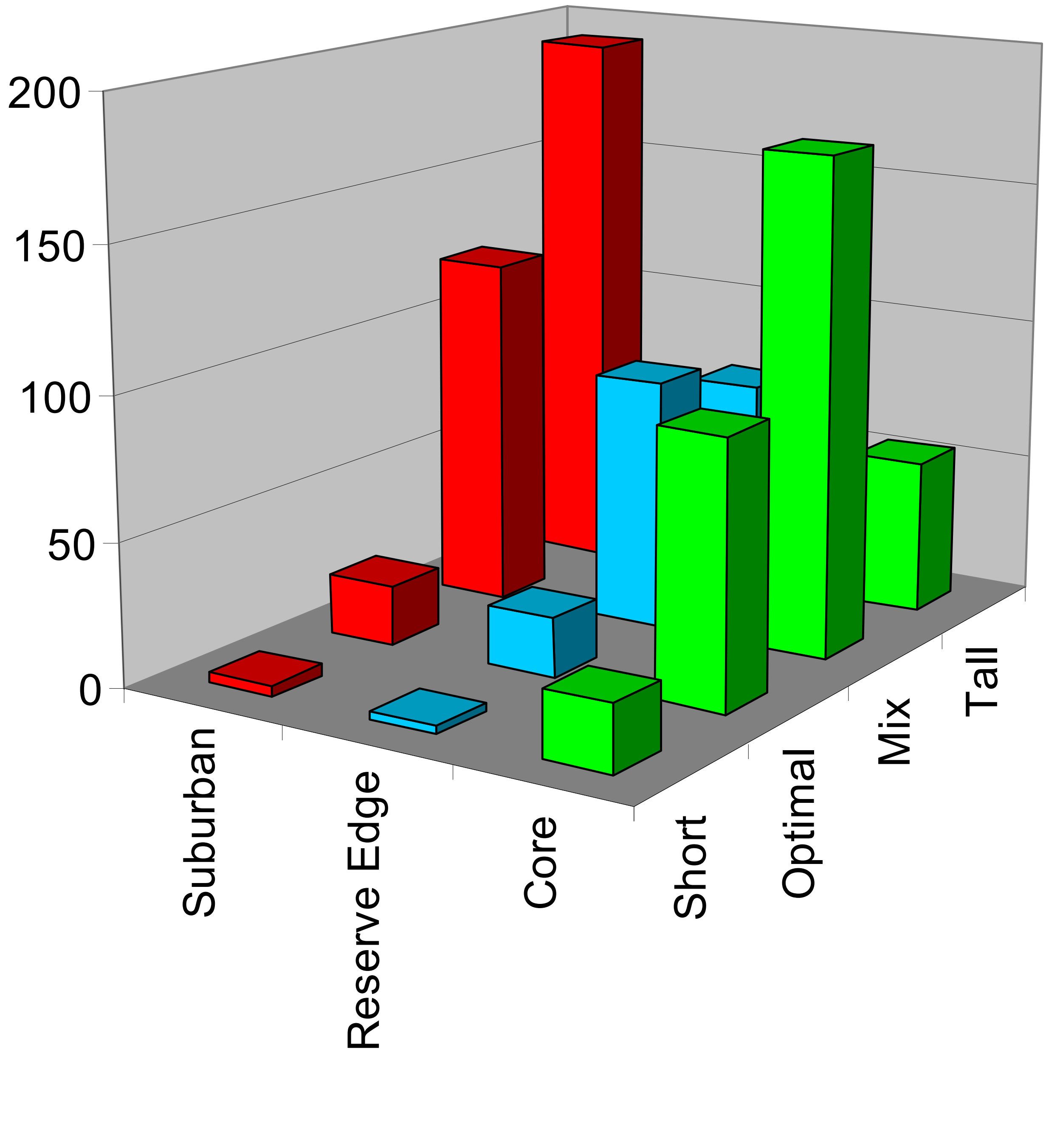


Figure 9. The number of potential territories (y-axis) in relation to metapopulation and scrub height arrangement.

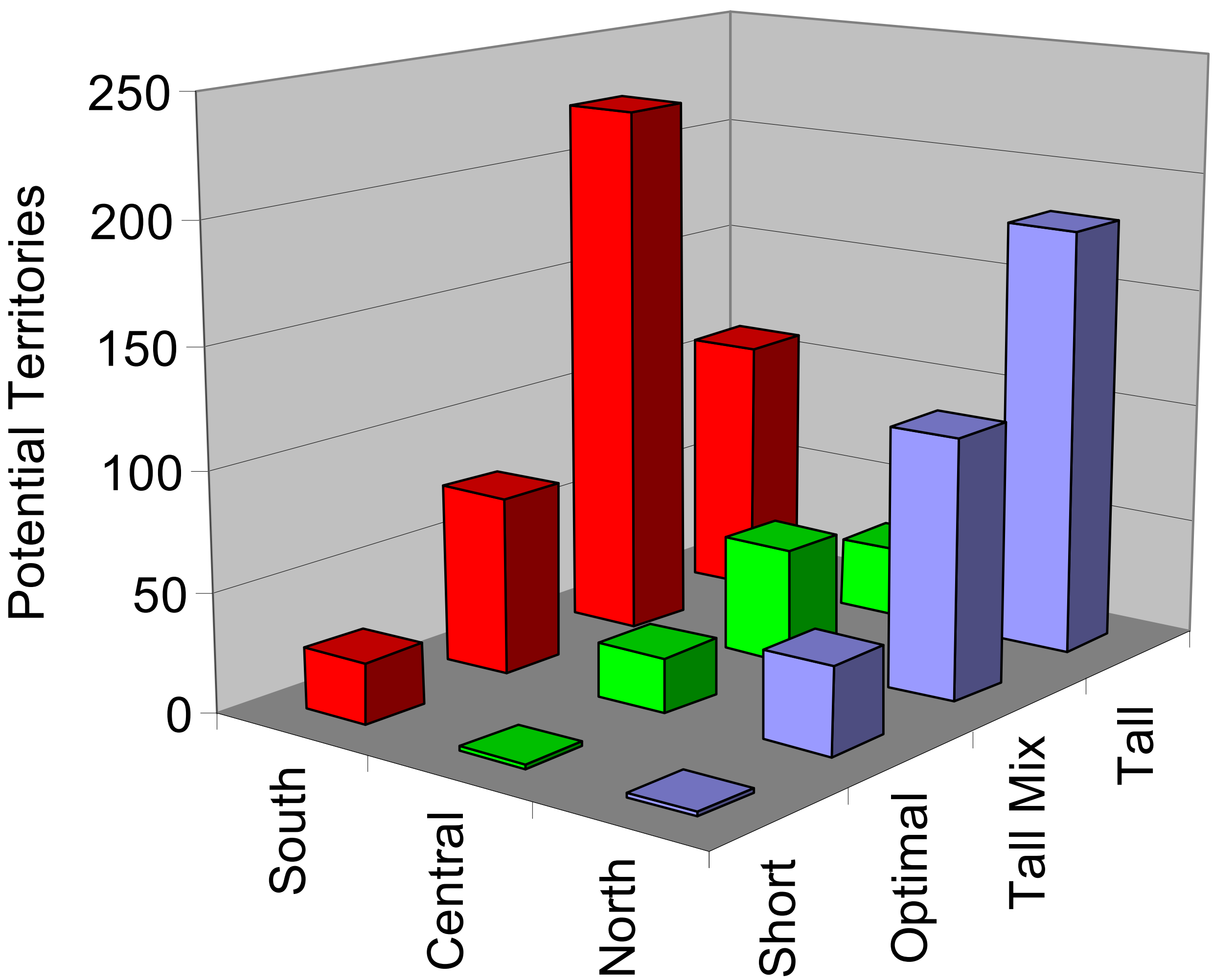


Figure 10. The number of potential territories (y-axis) in relation to protected status and scrub height arrangement. Protected territories occurred in areas purchased for conservation. Proposed territories were only proposed for acquisition. No acquisition has yet been proposed by conservation acquisition organizations for unprotected territories.

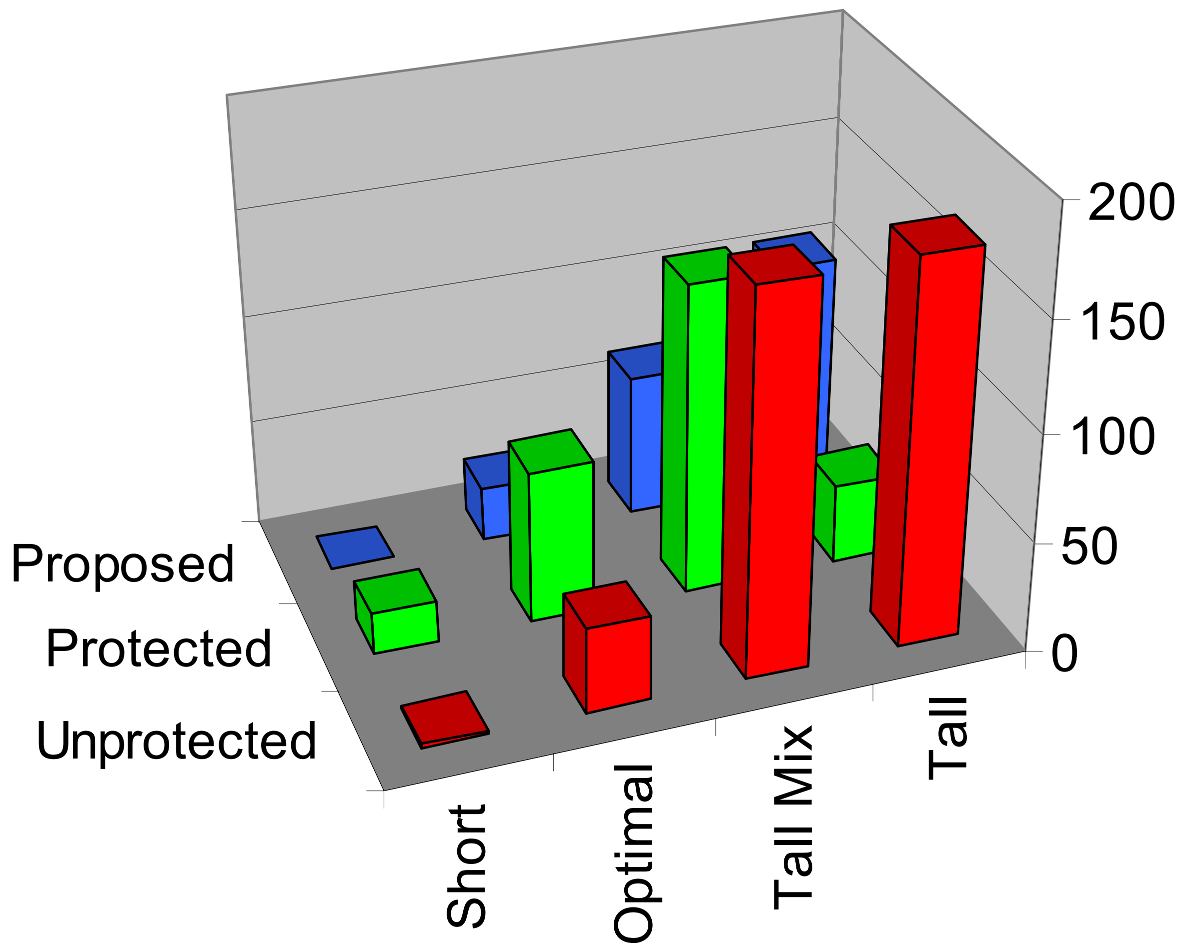


Figure 11. The number of potential territories (y-axis) in relation to scrub height arrangement and oak cover. Primary territories had oak scrub on well-drained soils. Secondary and tertiary territories occurred entirely on poorly-drained soils. Secondary territories had patches of >50% scrub oak cover that were >0.4 ha.

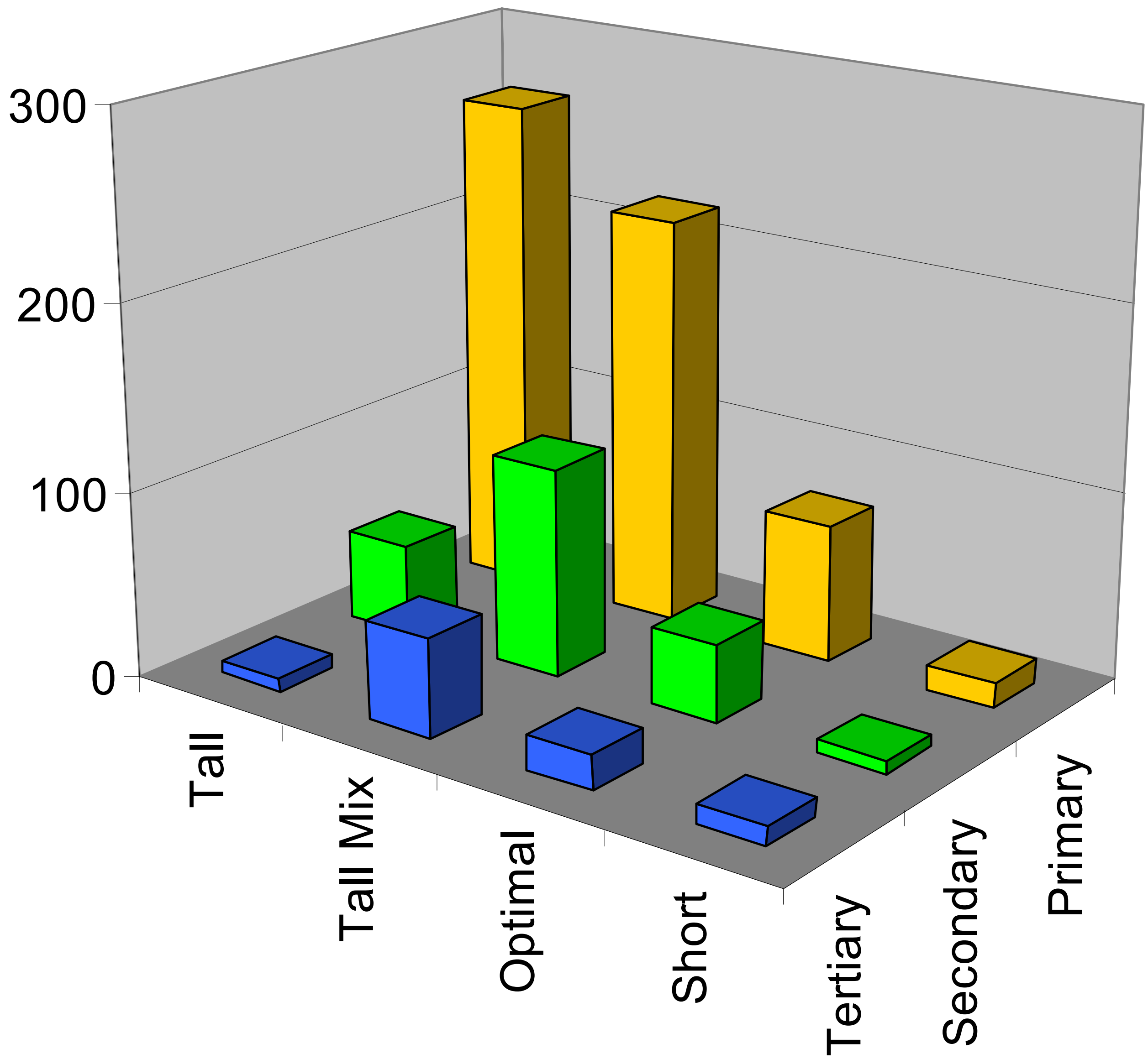


Figure 12a. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) North of Buck Lake.

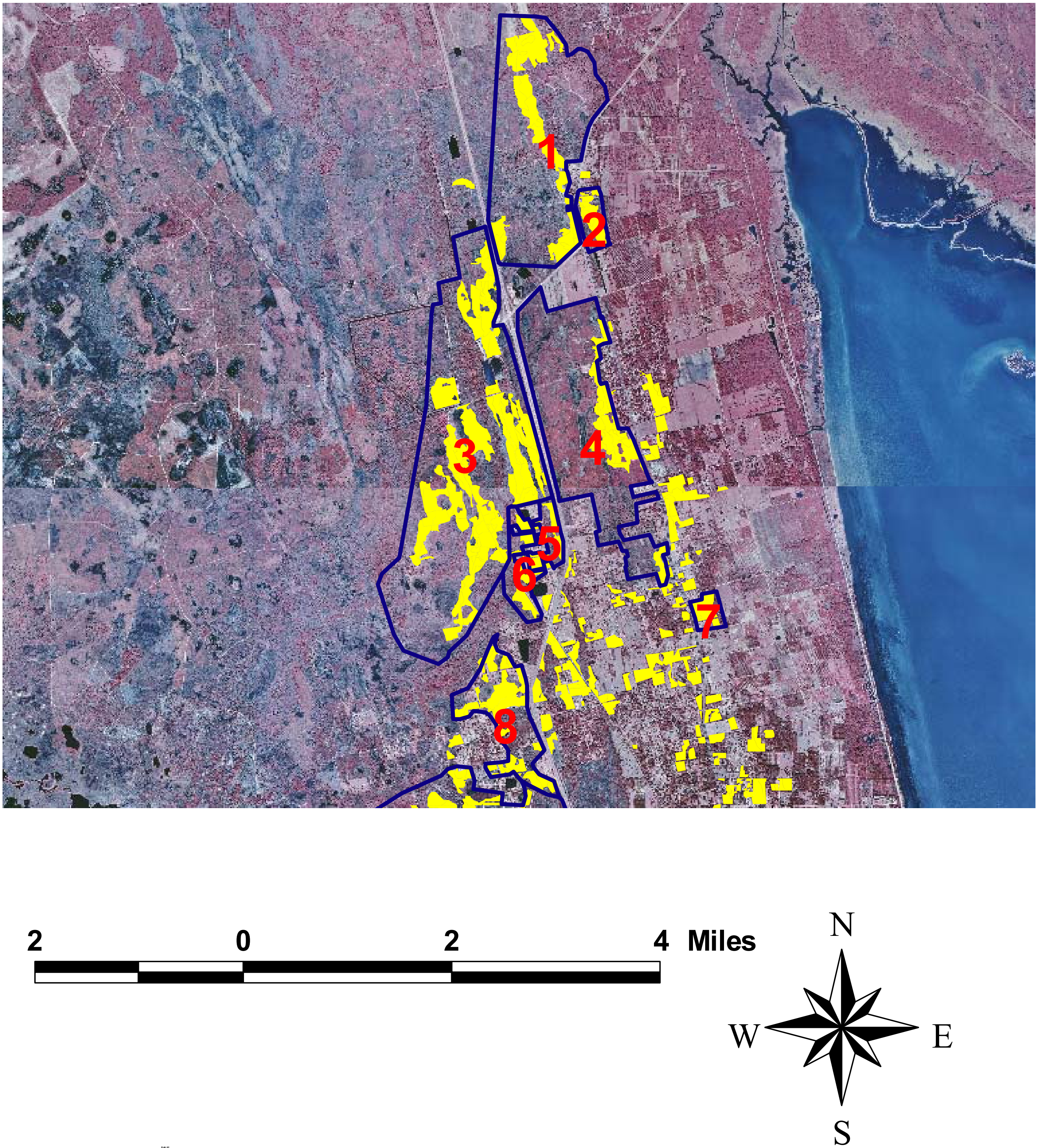


Figure 12b. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) from Buck Lake to Fox Lake

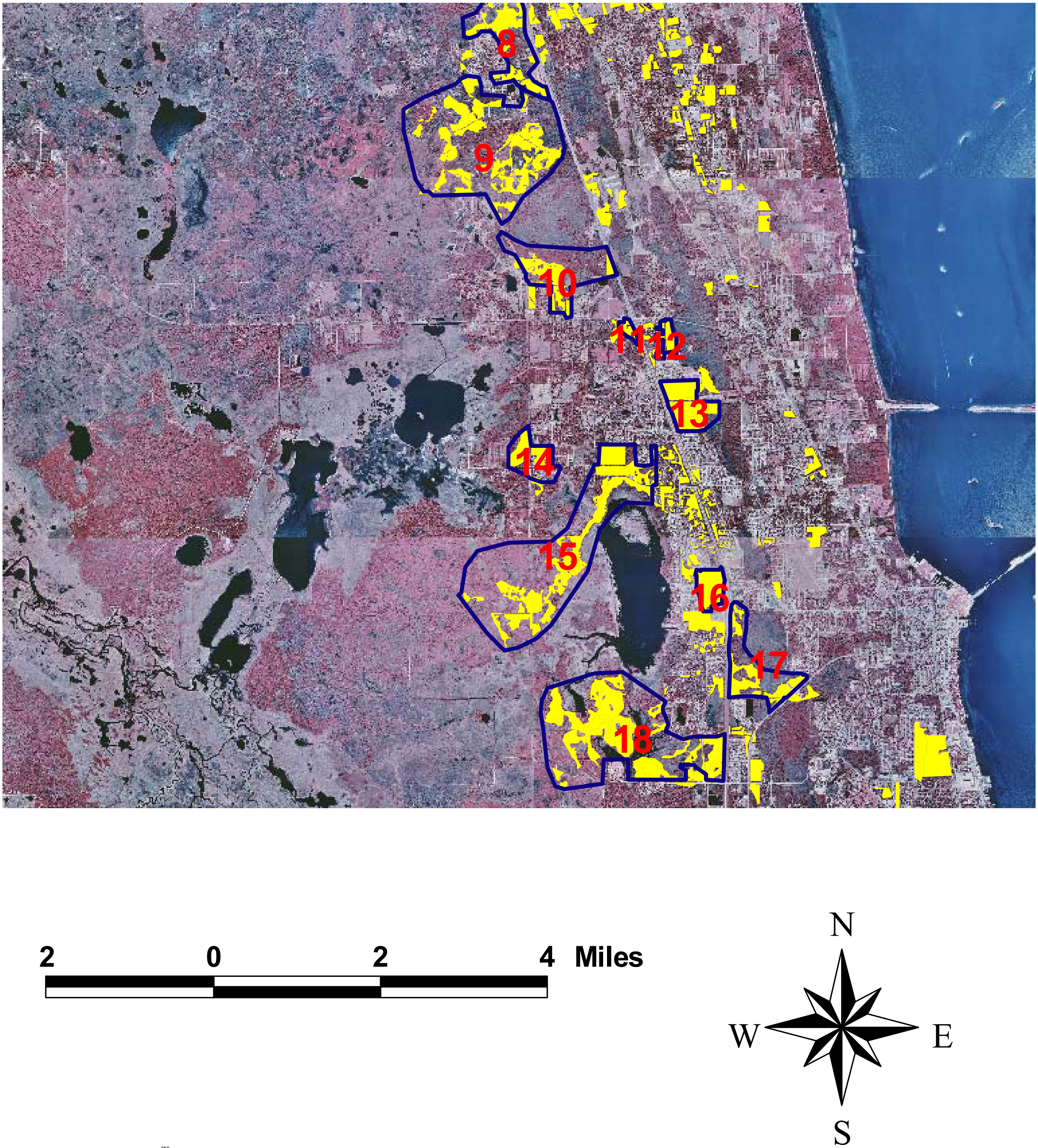


Figure 12c. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) Near Tico.

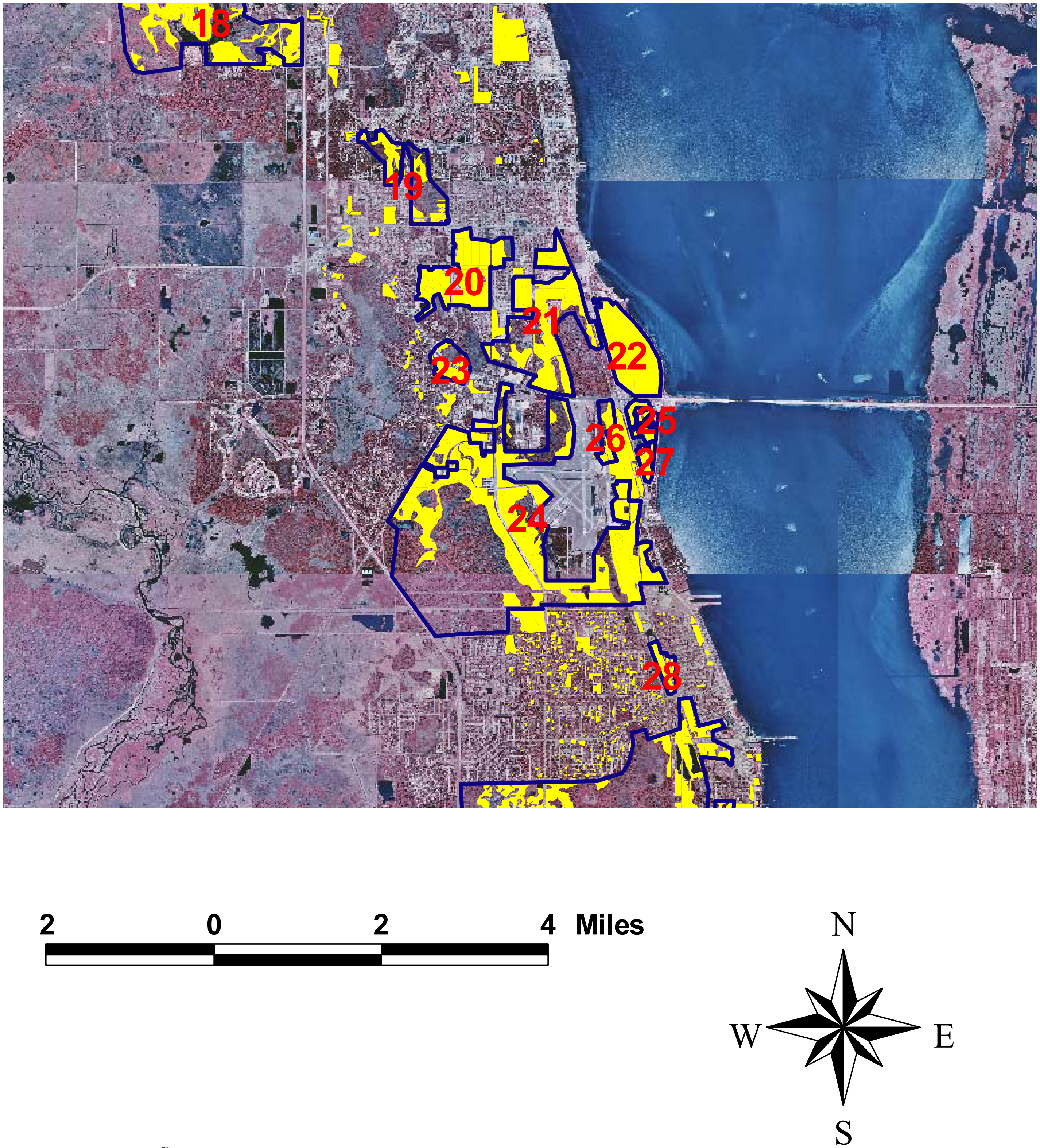


Figure 12d. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) Near Port St. John.

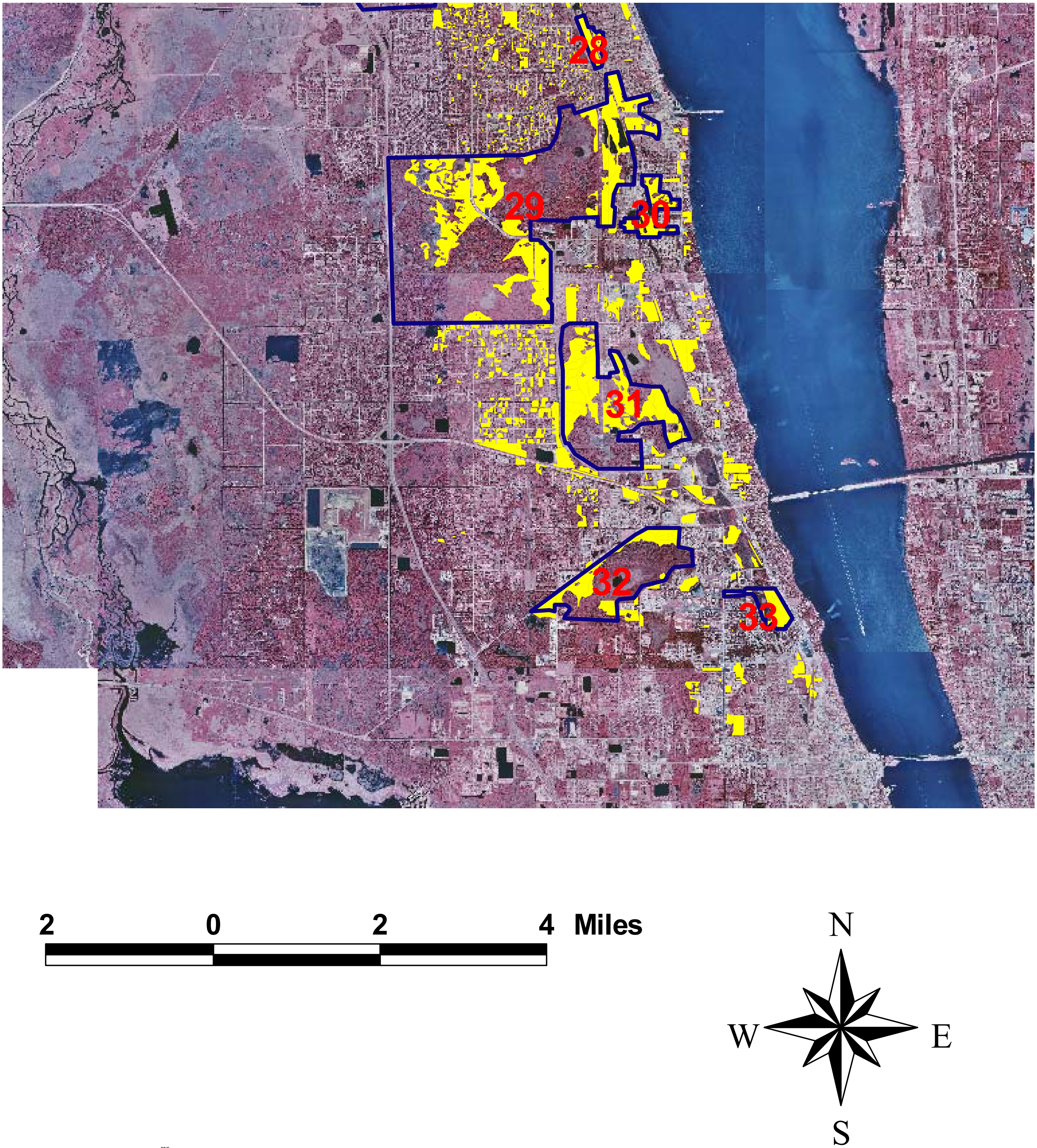


Figure 12e. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) from Cocoa to Viera.

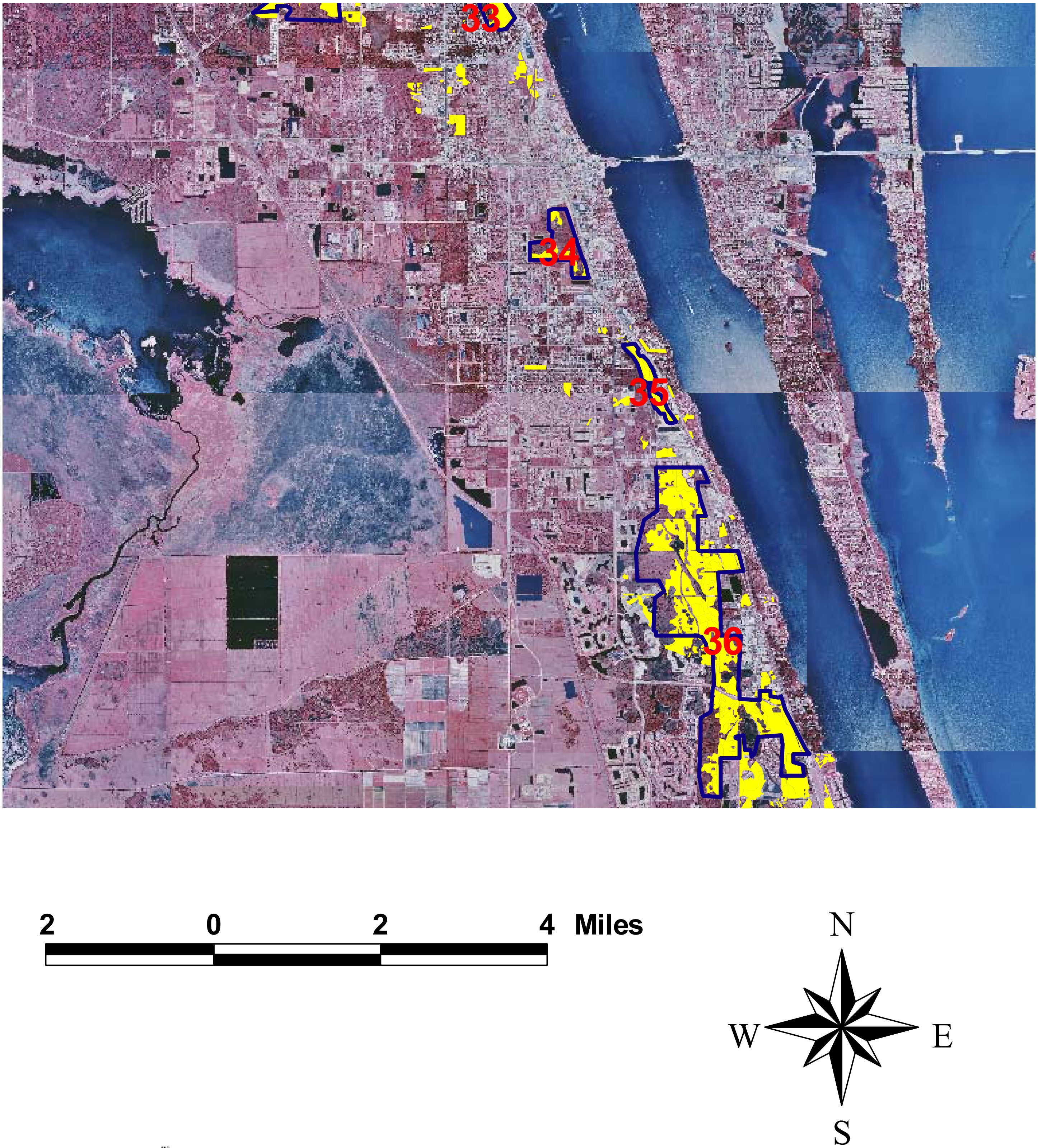


Figure 12f. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) near Wickham.

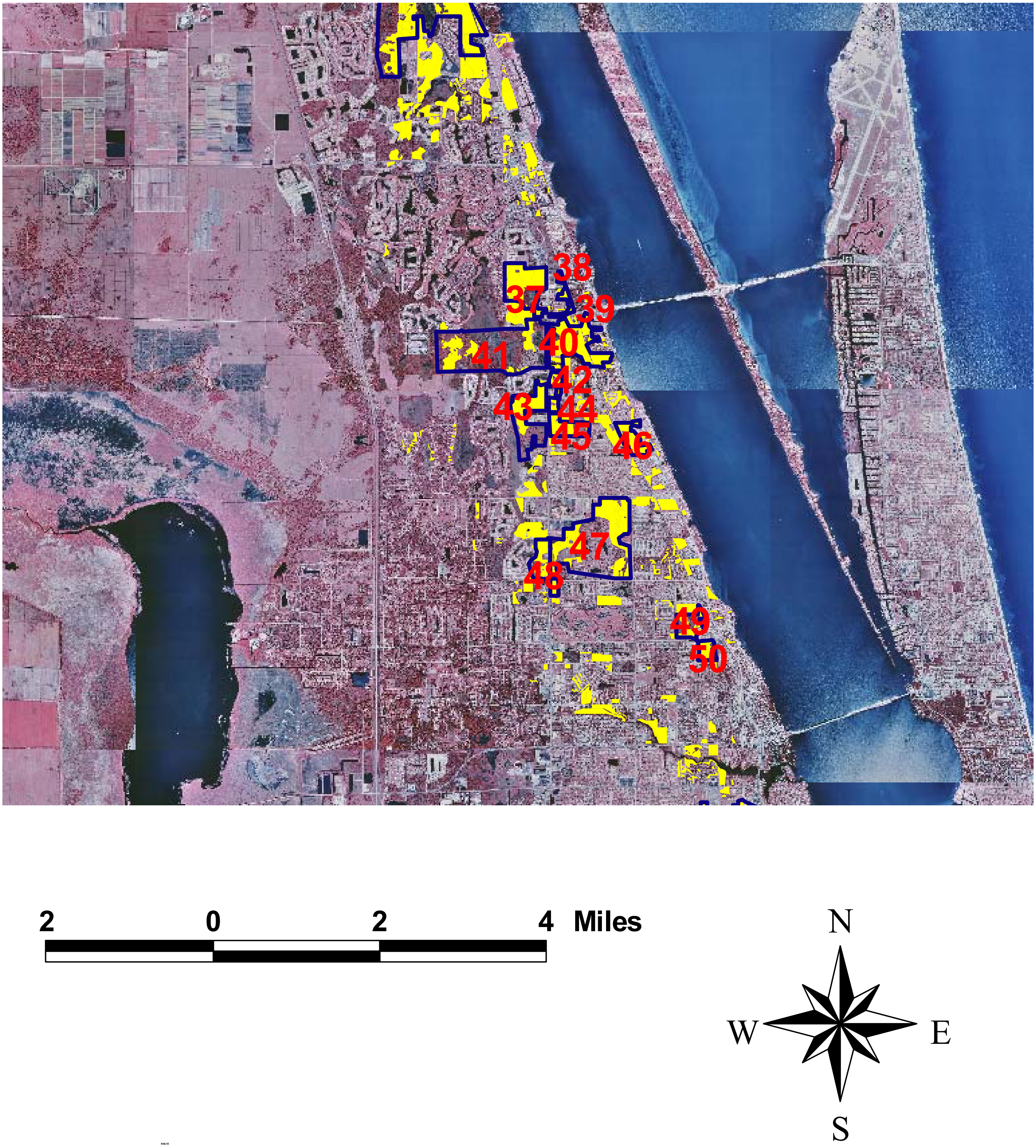


Figure 12g. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) near Melbourne.

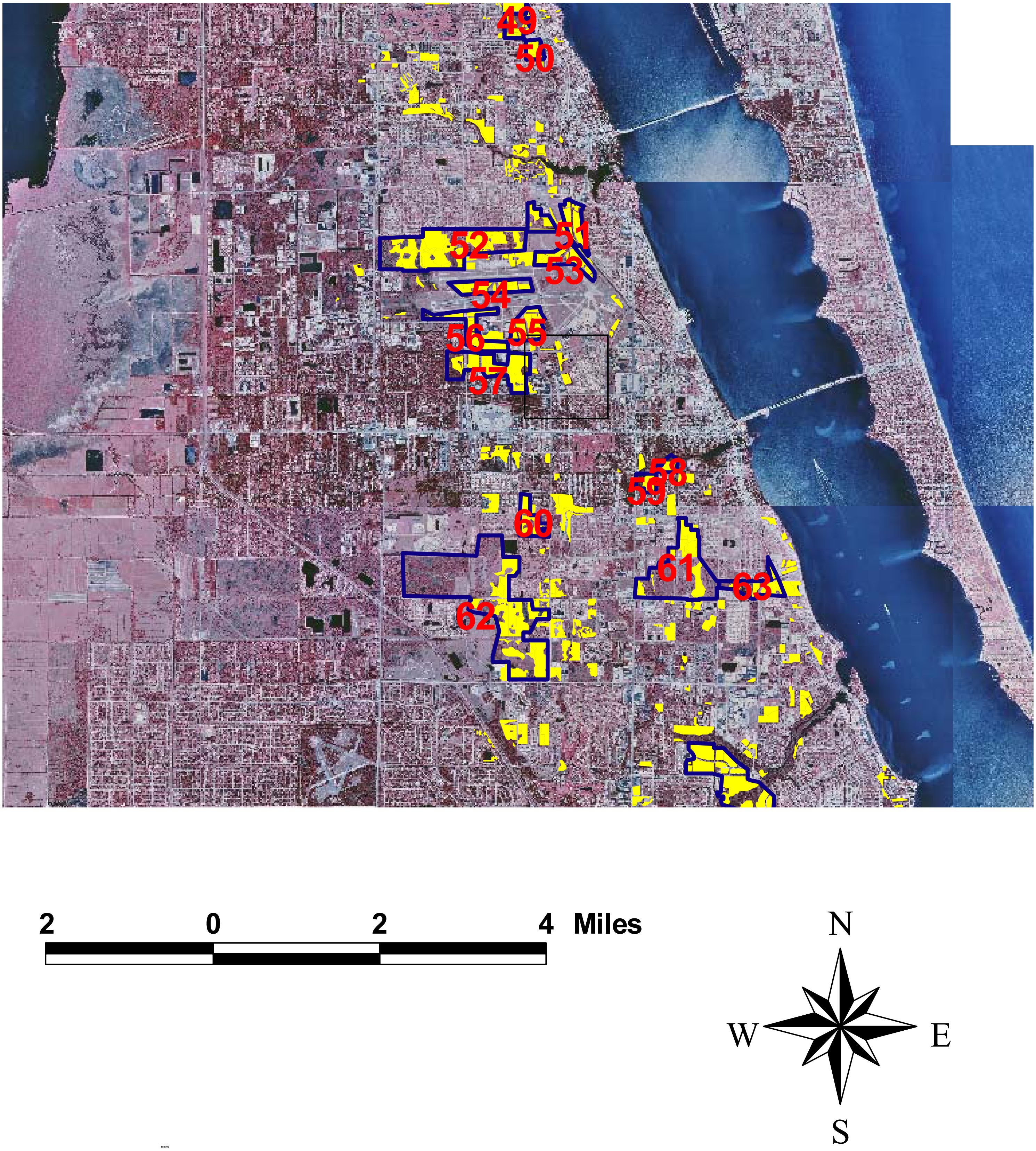


Figure 12h. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) from Malabar to Grant.

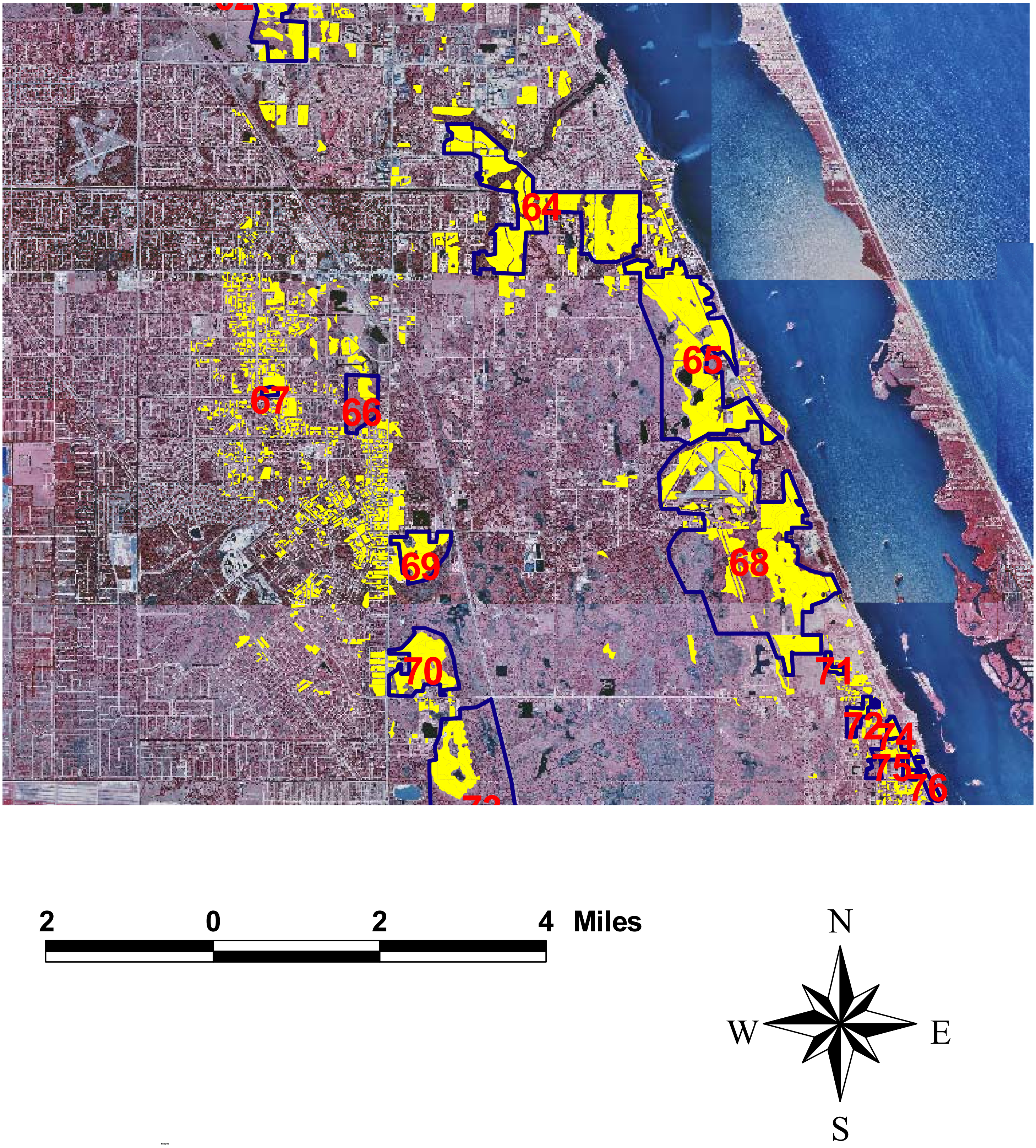


Figure 12i. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) from Grant to Sebastian.

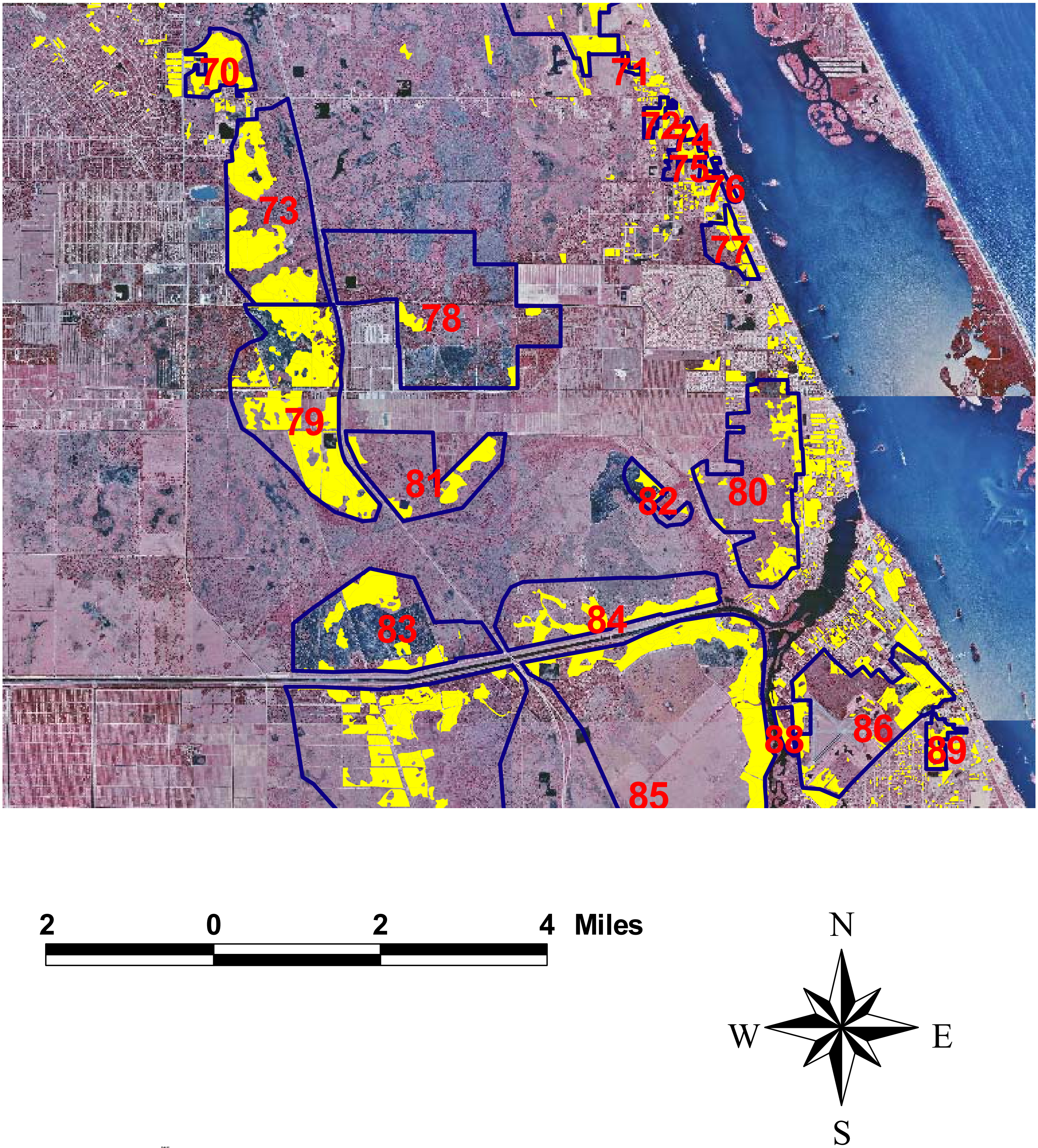
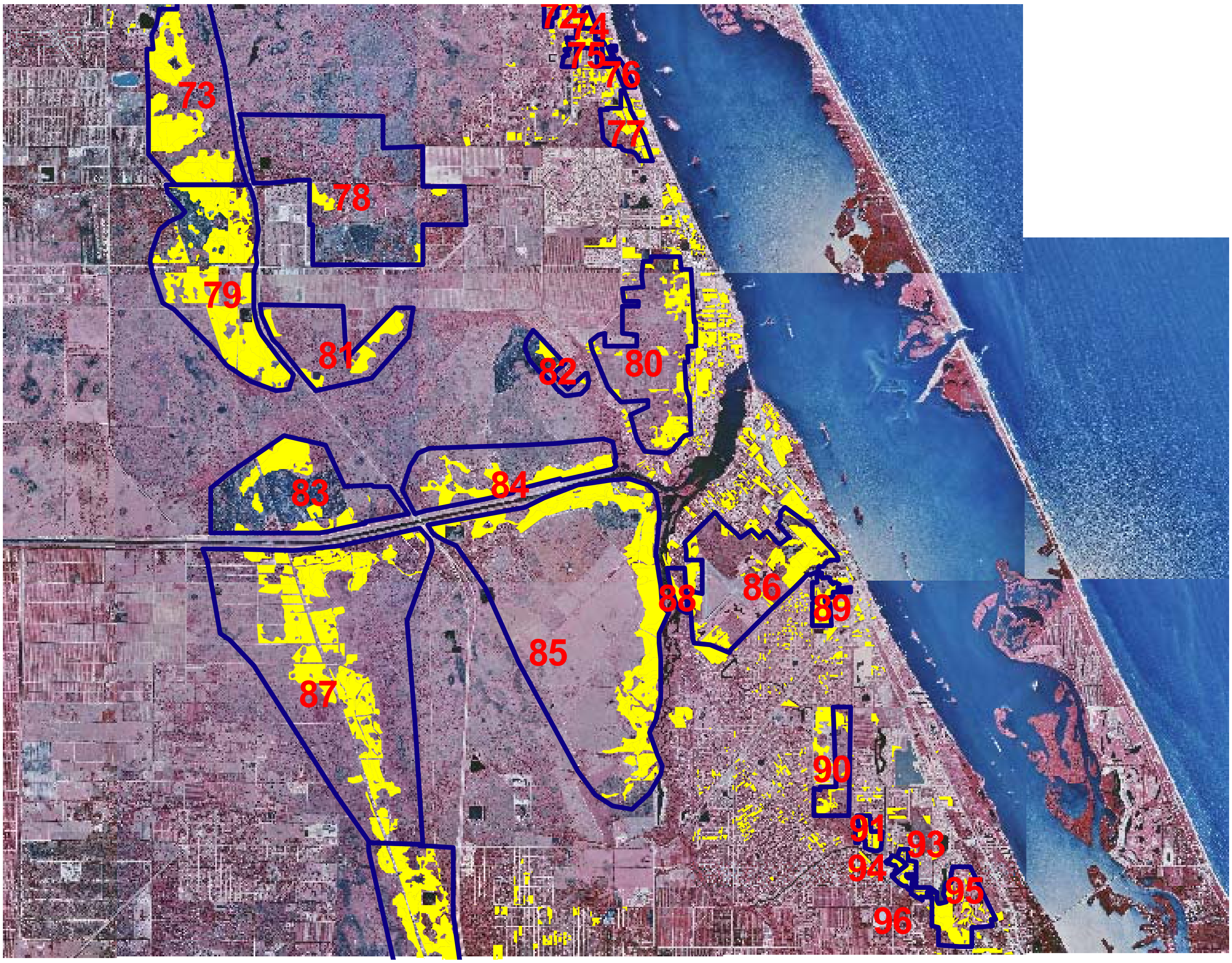
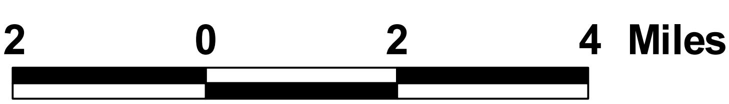


Figure 12j. Potential Scrub Reserve Units (blue lines) and Potential Habitat (yellow) near Sebastian.





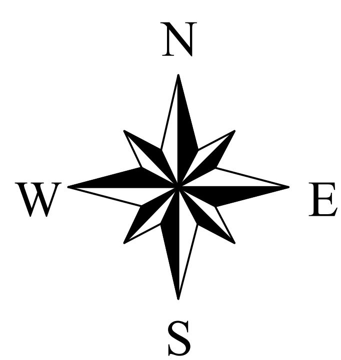


Figure 13a. Territory Clusters and Potential Reserve Units (PRU Identifiers in Red) in the North Brevard Metapopulation.

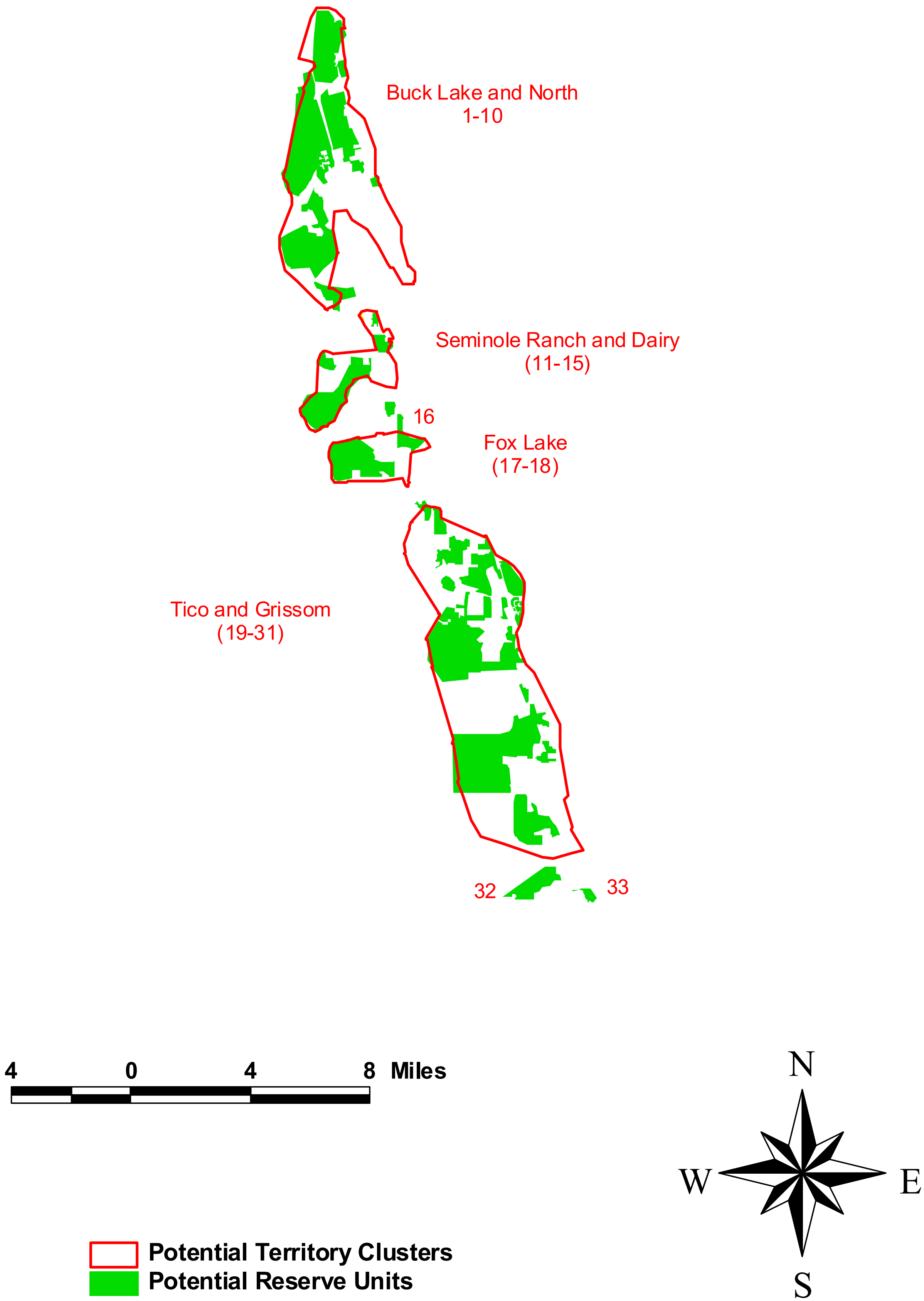


Figure 13b. Territory Clusters and Potential Reserve Units (PRU Identifiers in Red) in Central Brevard and the Northern Part of South Brevard-Indian River-St Lucie Metapopulation.

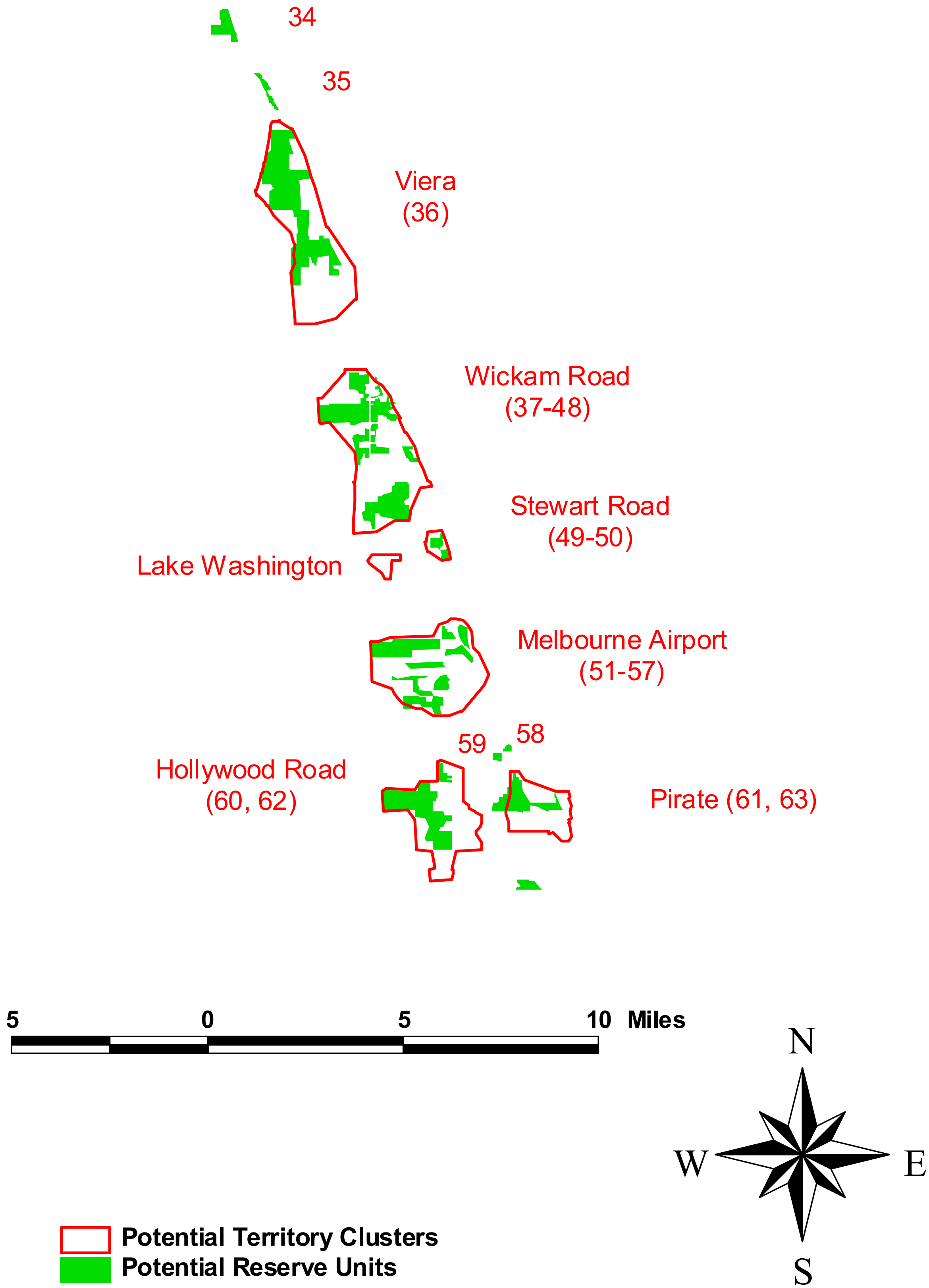


Figure 13c. Territory Clusters and Potential Reserve Units (PRU Identifiers in Red) in the Central Part of South Brevard-Indian River-St Lucie Metapopulation). PRUs Were Not Mapped South of Wabasso on the Atlantic Coastal Ridge or South of SR60 on the Ten Mile Ridge.

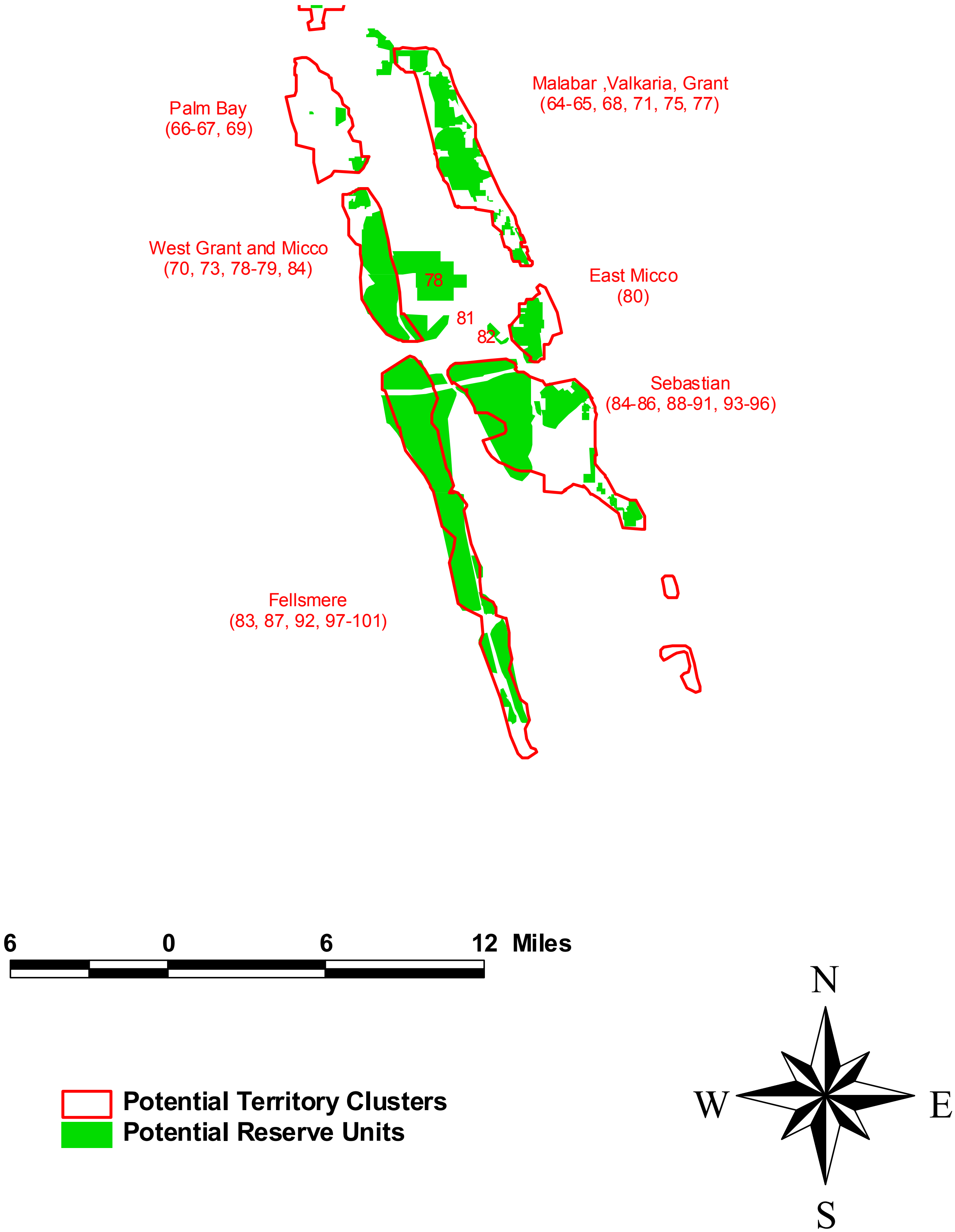


Figure 14a. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) from Buck Lake North.

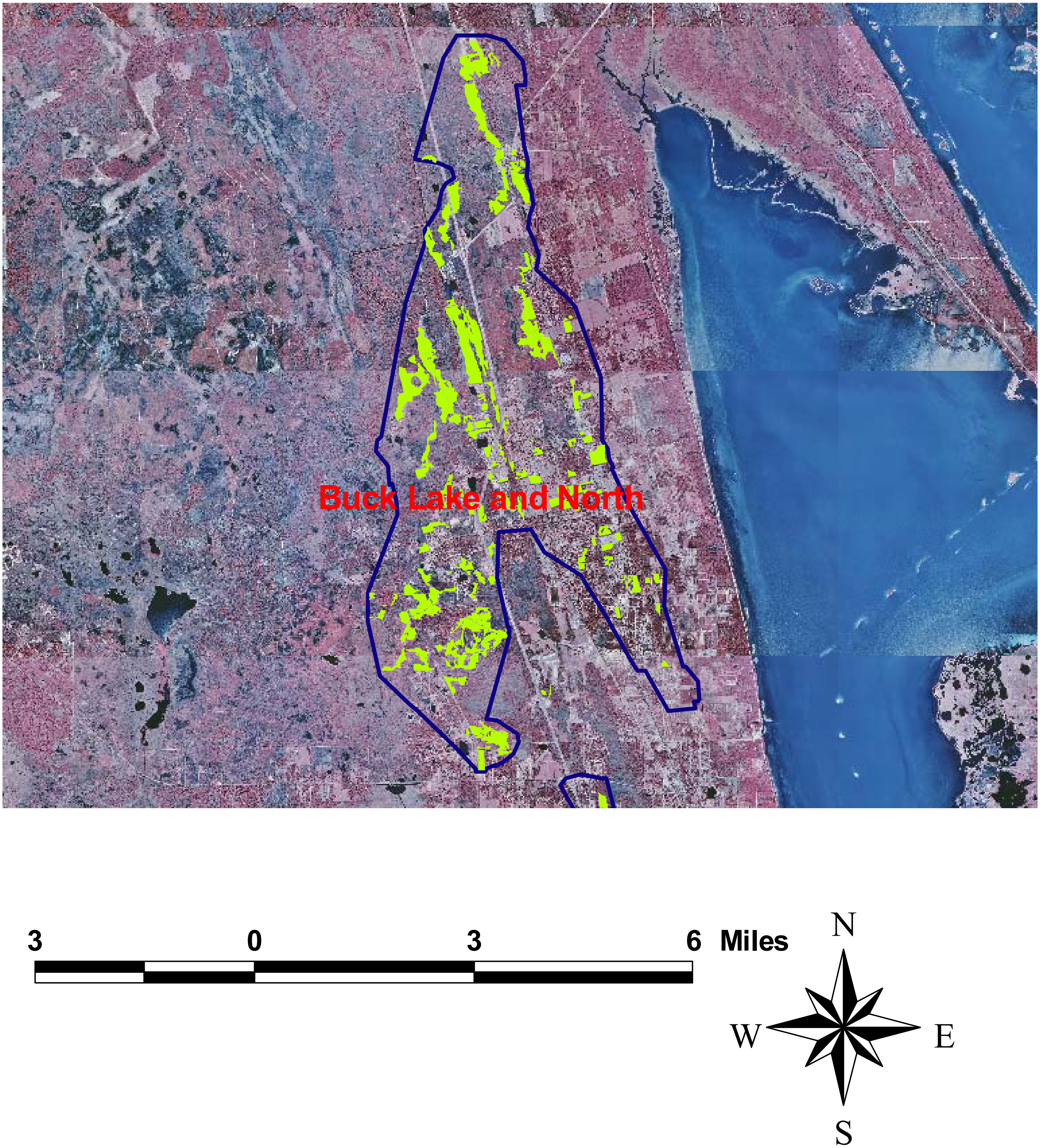


Figure 14b. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) near South Lake.

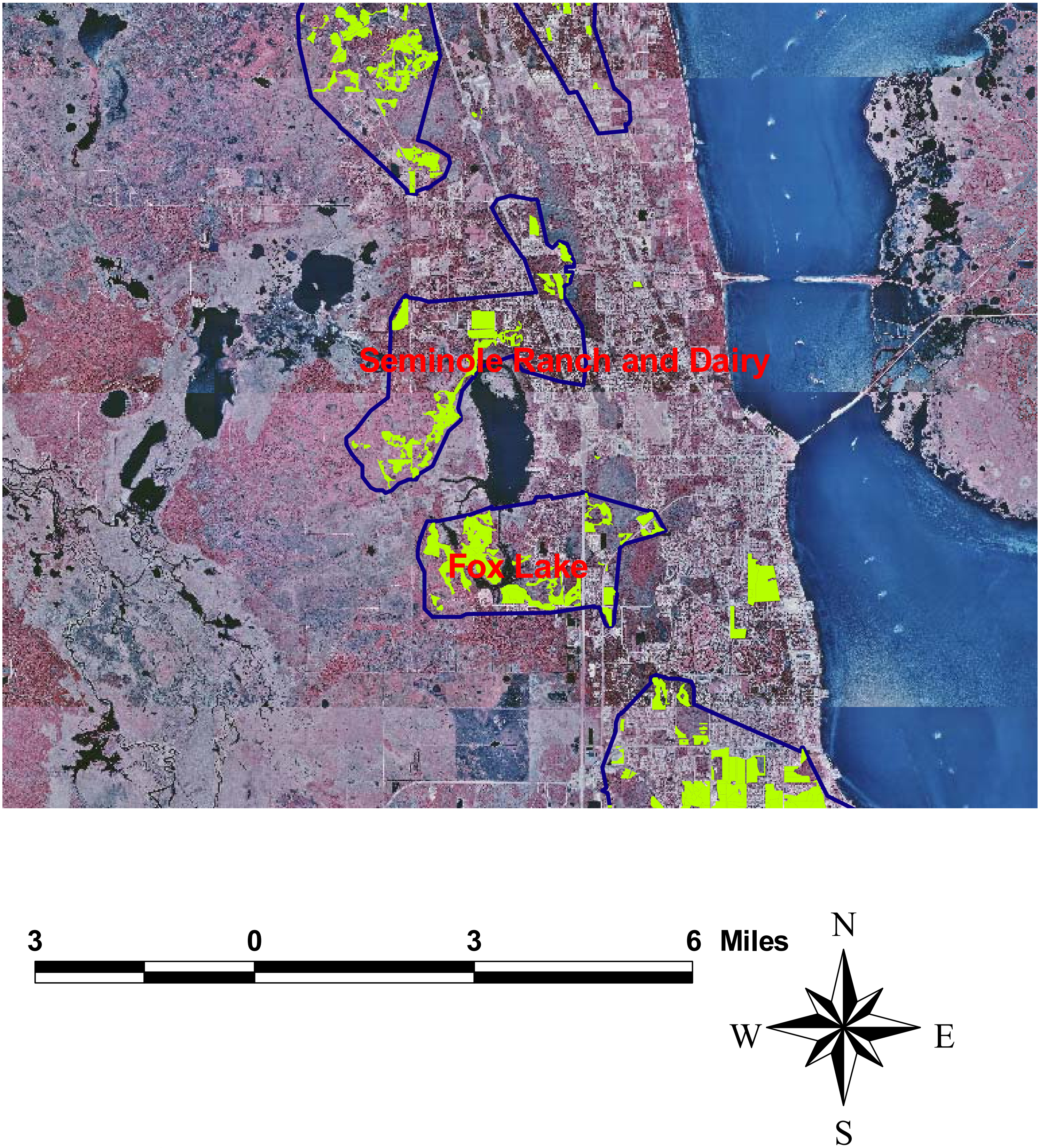


Figure 14c. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) near Tico.

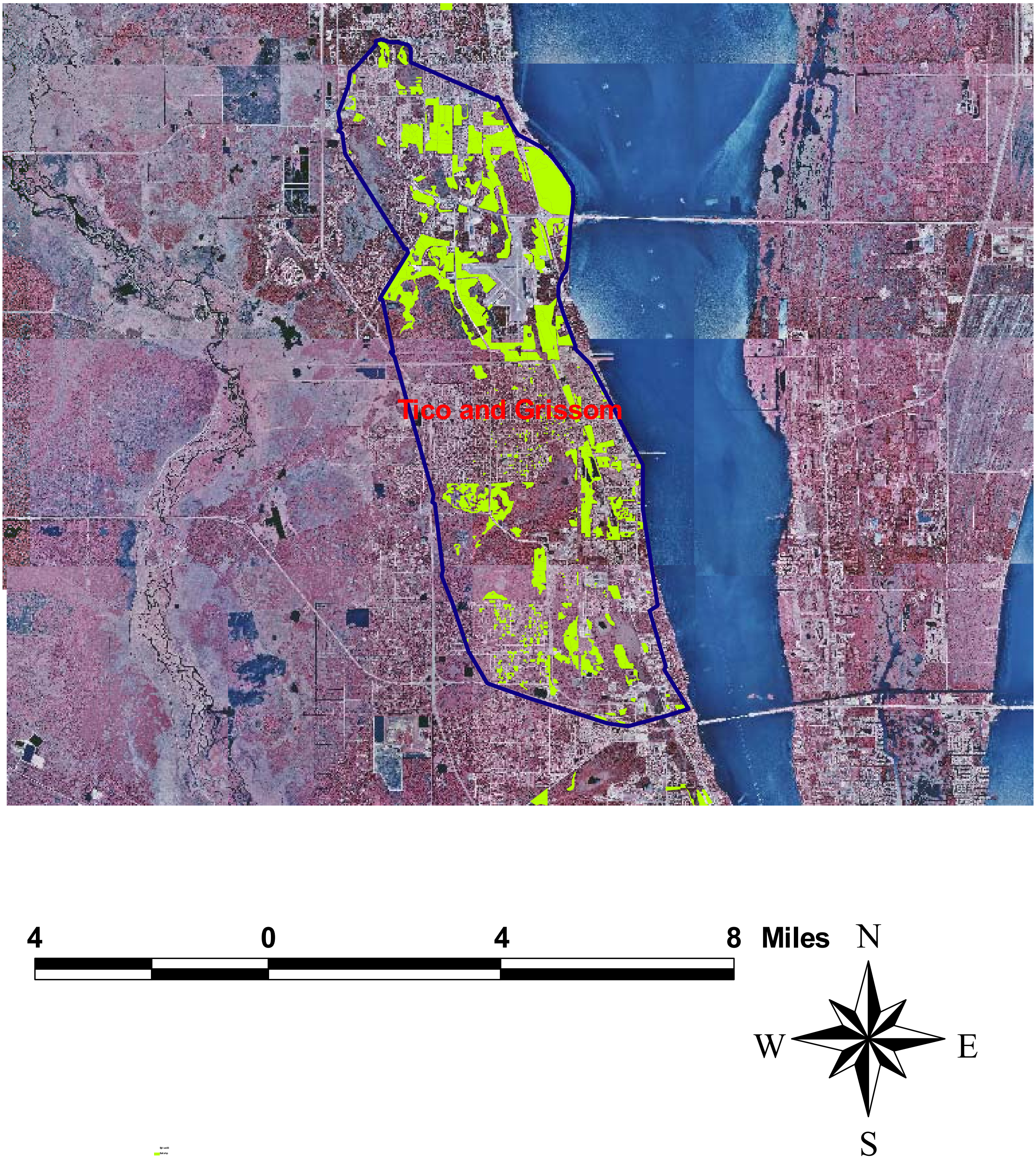


Figure 14d. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak from Titusville to Viera.

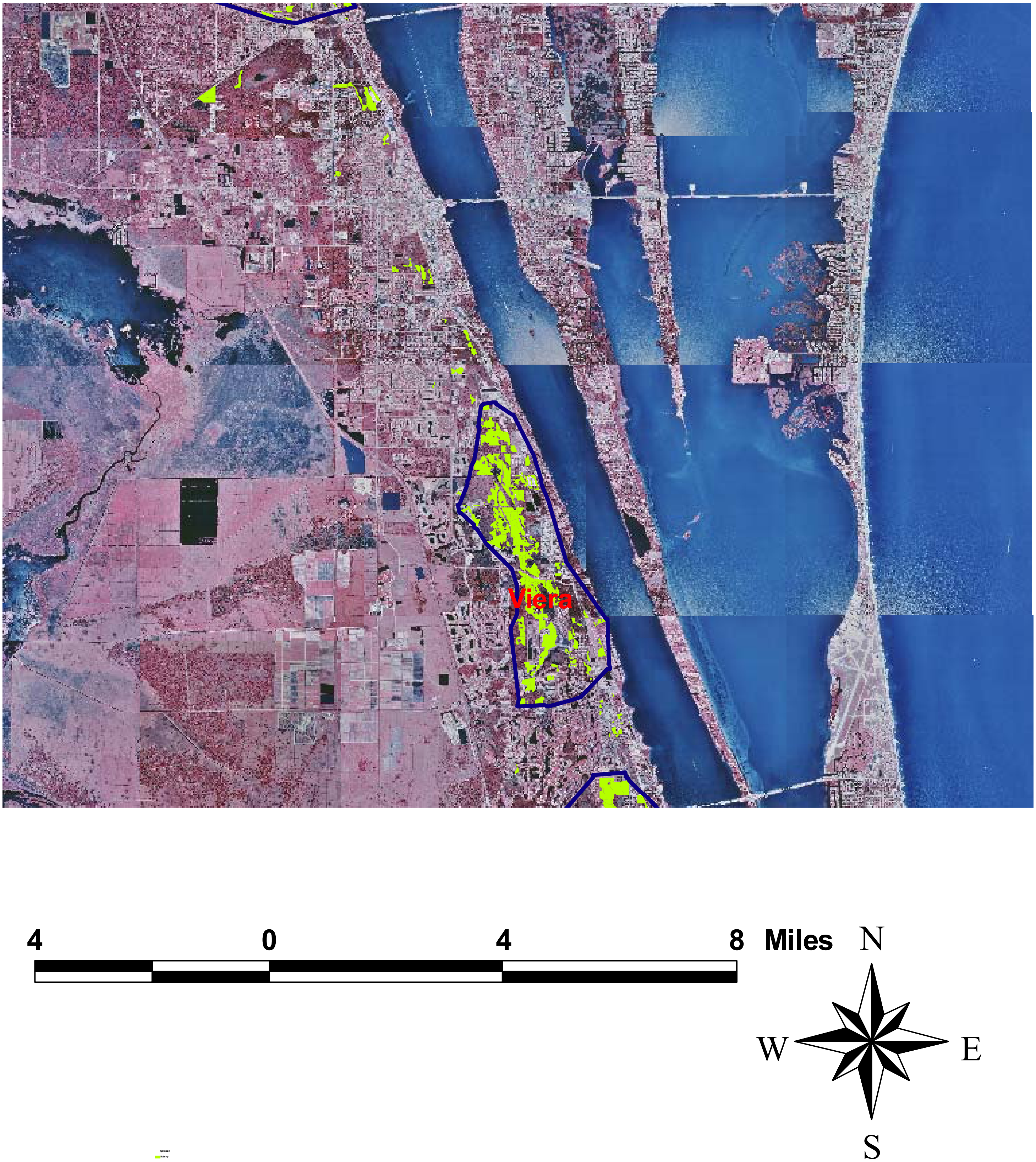


Figure 14e Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) from Viera to Melbourne.

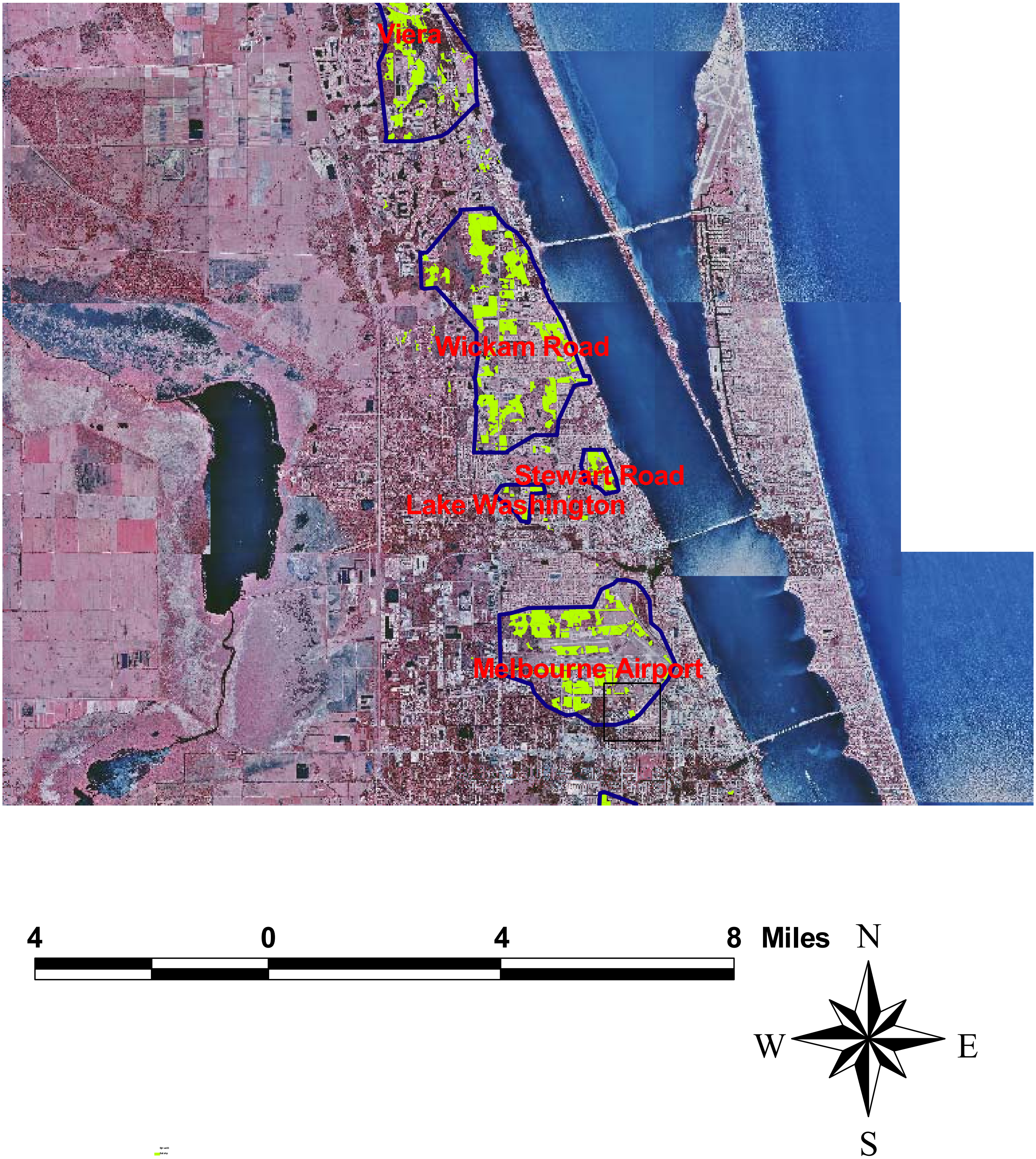


Figure 14f. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) from Melbourne to Grant.

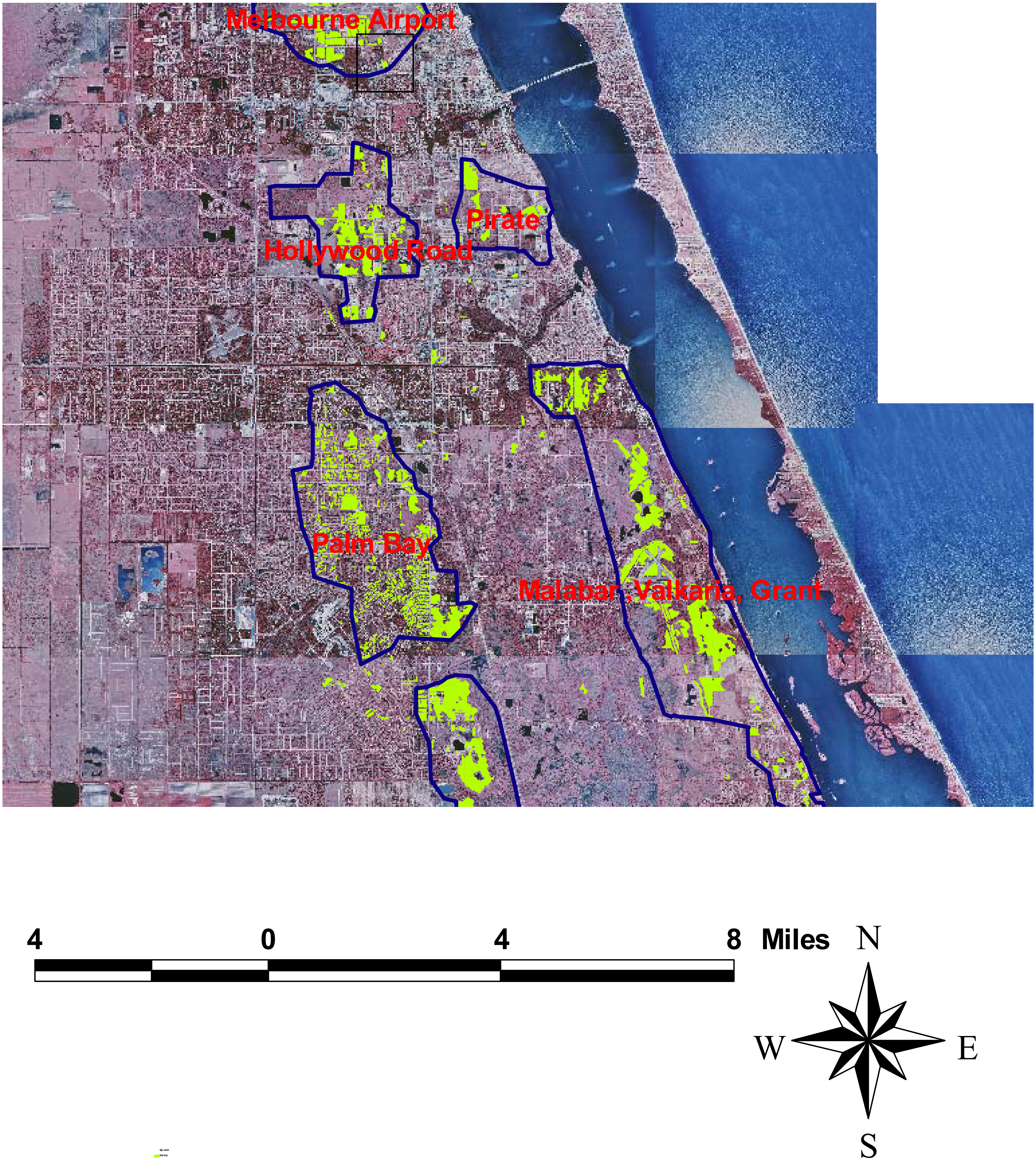
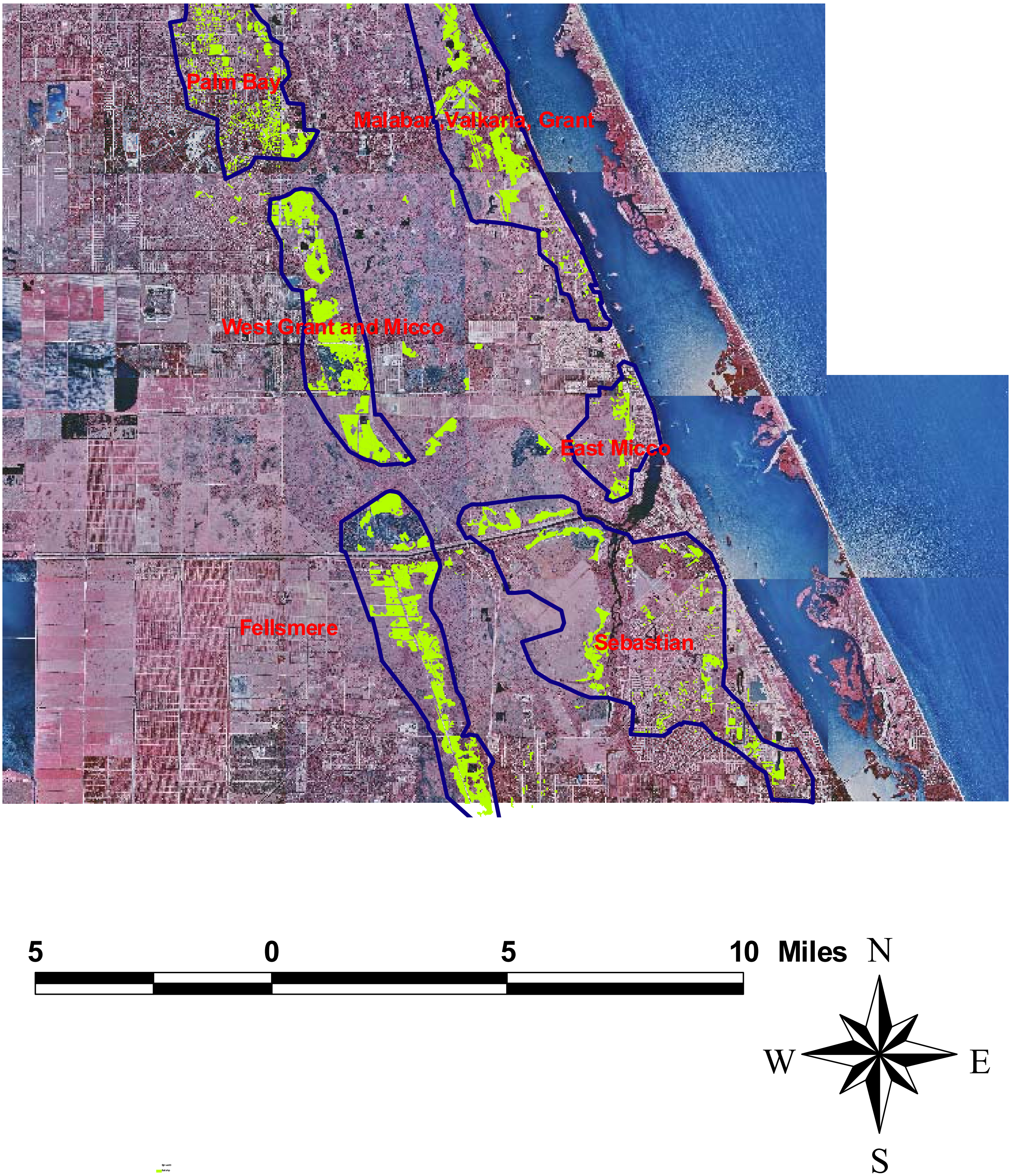


Figure 14g. Territory Clusters (blue lines) and Suitable Oak and Palmetto-oak (lime) from Palm Bay to Sebastian.



Territory Occupancy and Population Arrangement. Approximately 40 territories were not affiliated with PRUs in 2002. Most of these territories occurred in the suburbs of Port, St. John, Palm Bay, and Sebastian Highlands.

Most territories on Carson Platt and Coracii sections of Sebastian Buffer Reserve were not counted in 1992. We believe this underestimate involved 36 territories. We suspect that population sizes were also underestimated along the Ten Mile Ridge south of Fellsmere Road. Underestimations occurred because the search image emphasized xeric scrub and access to some ranches was limited.

If we assumed that population sizes in 1992 were at least as great as Coracii and Carson Platt in 1992, the total 1992 population size would have been 407 pairs. Only the Central Brevard metapopulation did not decline since 1992 and no metapopulation approached its potential population size (Tables 5, 6, Figure 15), based on the habitat mapping results described in previous sections. The greatest difference between 2002 population size and potential population size occurred in the North Brevard metapopulation. Possible metapopulation structures suggested that the populations along the mainland of the central Forest Atlantic coast could be organized into 1-3 metapopulations (Table 5, Figure 7a).

If one excludes areas poorly surveyed in either 1992 or 2001 (Fox Lake, Coracii, Carson Platt, and Ten Mile Ridge South of C54 Canal), the decline for all metapopulations was 34% between 2001 and 1992. The estimated average annual growth rate was calculated as $231/351^{(1/10)} = 0.96$, which was an average population decline of 4% per year.

Table 5. Metapopulation Summary of Population Sizes.

Metapopulation	Breeding Pairs		
	1992	2002	Potential [a]
North Brevard	102	67	324
Central Brevard	50	59	104
South Brevard-Indian River-St Lucie	255	160	410
Combined	407	286	838

[a] Includes unoccupied PRUs that could be restored to enhance connectivity.
[b] Assumes that 1992 population sizes for Fox Lake, Carson Platt, and Coracii were at least as great as in 2002. Neither of these areas was surveyed in 1992.

Figure 15. Potential Population and Actual Population Sizes (2002) of Territory Clusters. The y-axis represents the number of territories. Data Arranged from North-to-South except for the Unoccupied PRUs.

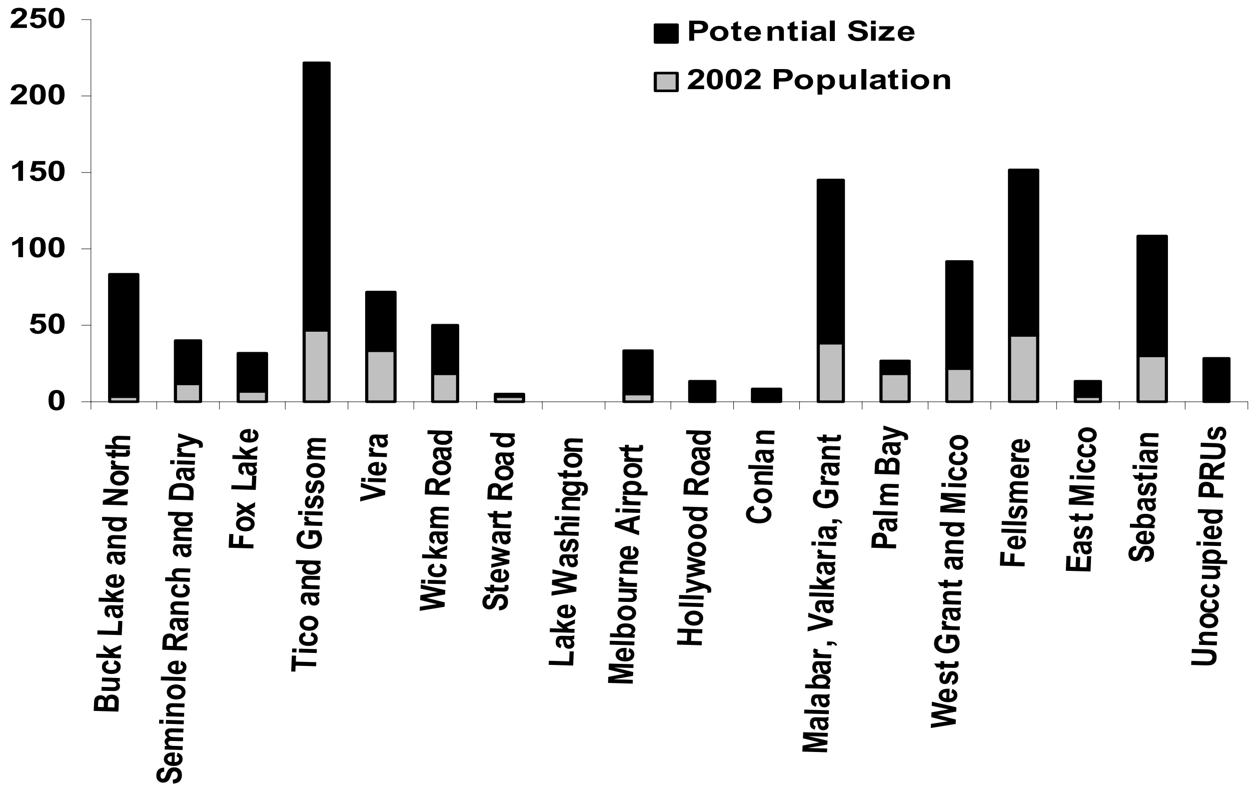


Table 6. Population Estimates Within Territory Clusters.

Metapopulation	Territory Cluster	Breeding Pairs 1992	Breeding Pairs 2002
North Brevard	Buck Lake and North	11	3
North Brevard	Seminole Ranch and Dairy	11	11
North Brevard	Fox Lake	8	6 [a]
North Brevard	Tico and Grissom	72	47
North Brevard	Total	102	67
Central Brevard	Viera	26	33
Central Brevard	Wickam Road	13	18
Central Brevard	Stewart Road	3	3
Central Brevard	Lake Washington	1	0
Central Brevard	Melbourne Airport	7	5
Central Brevard	Total	50	59
South Brevard-Indian River-St. Lucie	Hollywood Road	1	2
South Brevard-Indian River-St. Lucie	Conlan	5	2
South Brevard-Indian River-St. Lucie	Malabar, Valkaria, Grant	59	39
South Brevard-Indian River-St. Lucie	Palm Bay	53	19
South Brevard-Indian River-St. Lucie	West Grant and Micco	36	22 [b]
South Brevard-Indian River-St. Lucie	Fellsmere	42 [c]	43 [d]
South Brevard-Indian River-St. Lucie	East Micco	7	3
South Brevard-Indian River-St. Lucie	Sebastian	52 [e]	30
South Brevard-Indian River-St. Lucie	Totals [f]	255	160

[a] Areas with 5 pairs in 1992 were not surveyed in 2002. Estimates assume 5 pairs were present in 2002.
[b] Areas with 11 pairs in 1992 were not surveyed in 2002. Estimates assume 11 pairs were present in 2002.
[c] Areas with 27 pairs in 2002 were not surveyed in 1992. Estimates assume these were present in 1992.
[d] Areas with 12 pairs in 1992 were not surveyed in 2002. Estimates assume these were present in 2002.
[e] Areas with 9 pairs in 2002 were not surveyed in 1992. Estimates assume these were present in 1992.
[f] Excludes areas south of Sebastian and Fellsmere that had 21 pairs in 1992.

Figure 16a. Population structure using the buffer model described by Stith (1996) to define subpopulations and metapopulations but applying the buffers to potential territory clusters instead of estimated territory locations. This probably best represents current population structure: a North Brevard and a Central & South Brevard-Indian River-St. Lucie metapopulation.

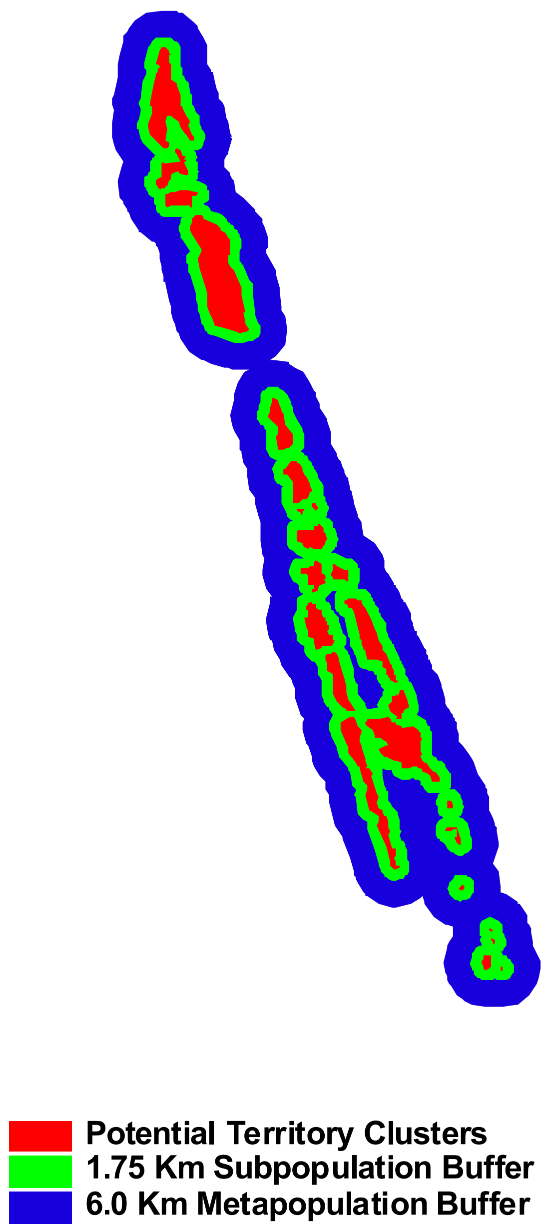


Figure 16b. Population structure using the buffer model described by Stith (1996) to define subpopulations and metapopulations but applying the buffers to all Potential Reserve Units and assuming that populations within them are recovered and all habitat becomes occupied. This scenario is based on habitat potential and suggests that one option could be to manage the metapopulations as one.

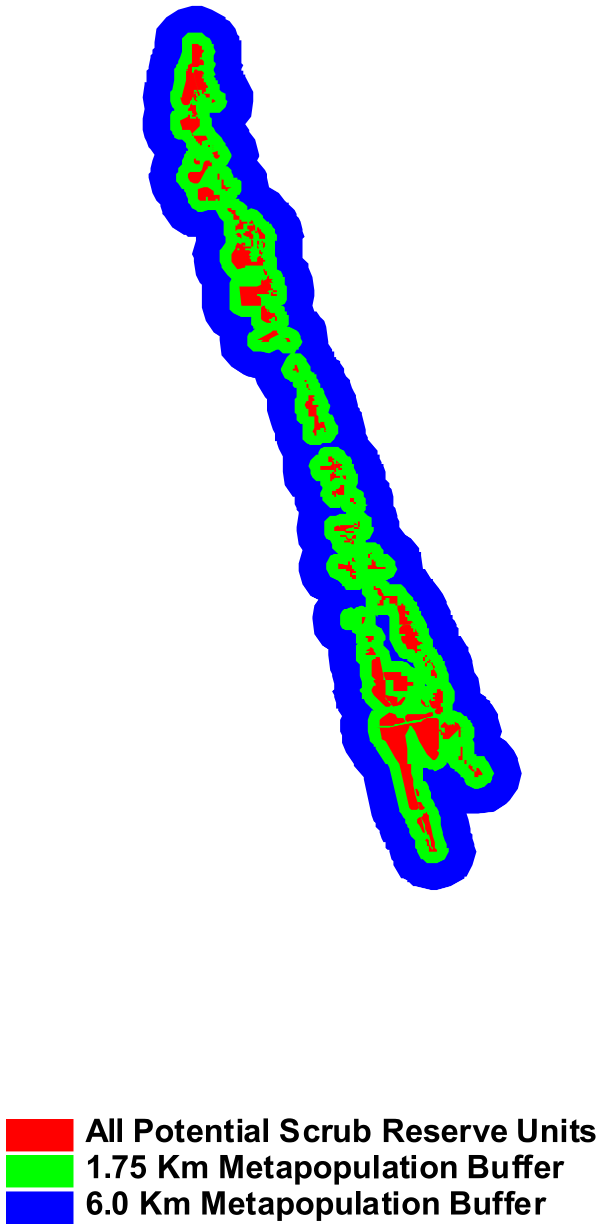
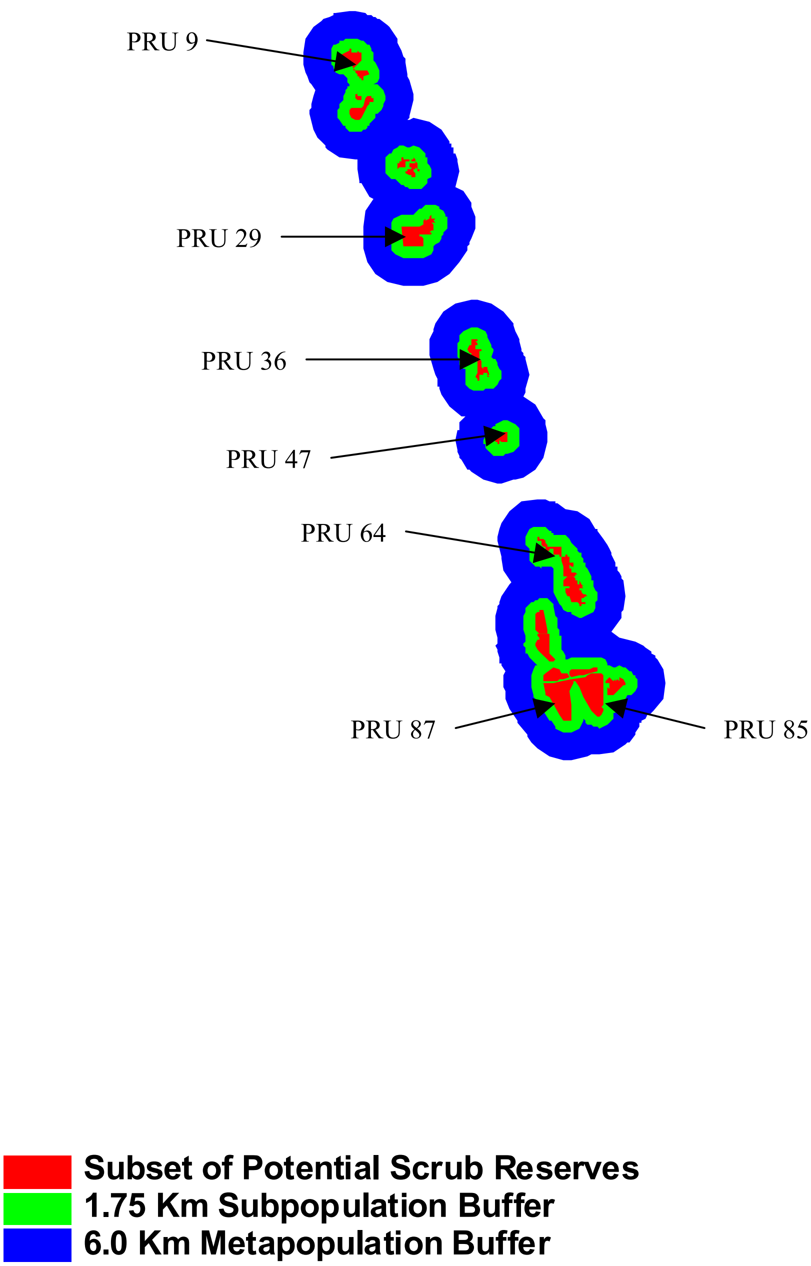


Figure 16c. Population structure using only a subset of Potential Reserve Units (PRUs). This assumes that populations in the smallest PRUs become extirpated and that all habitat is destroyed in PRUs that have no habitat currently acquired for conservation. This is a likely scenario if no new conservation acquisitions are planned. The result is that the 3 metapopulations become distinct and many subpopulations become widely separated.



3.3 Discussion

Potential Population Size. Potential population size is often estimated by dividing the area of xeric oak habitat by 10 ha. Dividing the area of xeric habitat by 10 ha resulted in a potential population size of 354 territories, which was similar to other estimates (e.g., Swain et al. 1995). Dividing our estimate of palmetto-oak by 10 ha suggested there was enough habitat for another 482 territories, which more than doubled the potential population size. Independent mapping studies by the Brevard County Natural Resources Department (2002) produced similar increases in estimated habitat. Therefore, the estimated amount of potential habitat has increased over time even though the actual amount of potential habitat has decreased because of rapid urbanization (Toland 2001). This occurred because our knowledge of species-specific habitat relationships has increased and because the application of land cover maps that are not specifically designed to map habitat of specialized species can result in many potential errors (Breininger et al. 1991a, 1995; Breininger and Oddy 2001). Landcover maps usually cannot distinguish secondary and tertiary territories from mesic flatwoods that is devoid of scrub oaks and is unsuitable. Our habitat mapping and independent mapping by Brevard County Natural Resources explicitly considered habitat features within the flatwoods matrix that were important to scrub species.

The relative distribution of potential territories among xeric oak and palmetto-oak changed when applying the potential territory model, which more realistically allocated territories along xeric oak scrub ridges. Within PRUs, the potential territory model suggested 535, 209, and 89 territories respectively for primary, secondary, and tertiary territories. Thus, the number of territories in xeric oak (primary) increased and the number allocated to palmetto-oak (secondary and tertiary) decreased. This occurred because we limited the total number of territories to the maximum amount possible based on the sum of total oak and palmetto-oak and because we preferentially allocated territories from primary to secondary to tertiary until the total number of potential territories equaled the total based on a sum of all xeric oak and palmetto-oak. The increased proportion of primary territories occurred because xeric oak scrub ridges were narrow relative to grid cells so that grid cells were not entirely comprised of xeric oak scrub allowing a greater allocation of primary territories than would be expected if primary territories would have needed to be entirely comprised of xeric oak scrub. Real primary territories overlapping scrub oak ridges along Florida's Atlantic Coast also are only partially comprised of xeric scrub oak patches and include many smaller poorly-drained ridges, palmetto-lyonia, marshes and other cover types (Breininger et al. 1991a, 1995, 1998).

When landscape features permitted, we subjectively extended our PRU boundaries a few hundred meters beyond xeric oak scrub and palmetto-oak to buffer the ridges to enhance dispersal (see Stith 1999), reduce edge effects (see Mumme et al. 2000, Bowman and Woolfenden 2001), enhance prescribed fire (see Breininger et al. 2002), and because actual Florida scrub-jay territory boundaries extend for hundreds of meters past the focal habitat patches (Breininger et al. 1995, 1998). Consequently, the PRUs might be able to support more tertiary territories than we estimated. A large number of tertiary territories could only be supported if there was a continuously large excess of potential breeders because tertiary territories are sinks (see section 5.0 and Breininger and Oddy [2001]). This excess could only be sustained if habitat conditions were optimal and source territories exceeded sink territories (Breininger and Carter 2003). The proportion of a population that can be sustained in these areas will depend on the amount of sink habitat, the rate of population decline in sinks, and regional processes of productivity in sources and immigration into sinks (Dias 1996). This is further complicated by the cooperative breeding system and under what conditions jays choose to disperse into marginal habitat. Florida Scrub-Jays have propensities to avoid dispersing into some types of marginal habitat (Woolfenden and Fitzpatrick 1984, Fitzpatrick and Woolfenden 1986). The proportions of sinks that can be sustained by sources is best estimated using population models, because stage-based vital rates, environmental and demographic stochasticity, density dependence, dispersal propensities, catastrophes, and changing habitat conditions, make calculations too complicated using human intuition and simple math (Burgman et al. 1993, Akçakaya et al. 1999, Breininger et al. 2002). We kept our estimates of potential territories simple and conservative within PRUs in this report by using the maximum area of oak and palmetto-oak to provide a limit on the number of territories that could be supported within PRUs.

The proportion of primary, secondary, and tertiary territories that actually occur within landscapes can be estimated by the sample sizes for juvenile production in our study sites given that we attempted to quantify juvenile production in all territories within landscapes without preferentially studying jays in primary, secondary, or tertiary territories. These percentages were 63%, 31%, and 5% respectively for primary, secondary, or tertiary territories (Section 5, Table 9). The estimated percentages for the potential territory model were 64%, 25%, and 11% respectively for primary, secondary, or tertiary territories. These relative percentages were similar, although the proportion of territories occupied might have been greater if most habitat had not been of marginal habitat quality.

Regardless of these uncertainties, palmetto-oak allows the population to be much larger and better able to withstand environmental stochasticity (Pulliam 1988, Howe et al. 1991). This occurs because there is back-migration from suboptimal into optimal habitats (Breininger and Carter 2003, Breininger and Oddy unpublished manuscript). Palmetto-oak territories can also buffer oak scrub from human edge effects and they provide for greater connectivity.

Potential Conservation Areas. The population in 1992 was probably >400 pairs, which was the criteria for designating a core population (Stith et al. 1996). Therefore, the population could be designated a core population, making it one of the four largest populations within the species range. The potential habitat is sufficiently contiguous so that the three metapopulations could be considered as one based on Stith et al.'s (1996) criteria if habitat was restored and recolonized by Florida Scrub-Jays in areas that currently separate the metapopulations. Historical mapping indicates that the habitat was once contiguous (Duncan et al. unpublished data).

In Section 5.0 we document population exchange between the Central Brevard and South Brevard-Indian River-St Lucie metapopulations. Therefore, these could be considered the same metapopulation, which has a potential size that can exceed 400 pairs, although it might take time to reach such a recovery goal once enough habitat was acquired and restored. Given rampant human population expansion form Palm Bay to Cocoa, it is also likely that the Viera territory cluster might become its own separate metapopulation that would be vulnerable to extinction. The small territory cluster at Wickam Park might supplement the Viera population because Wickam Park is a Brevard County park, although it lacks a specific conservation plan.

Historical aerial photographs indicate that most potential territories were open savannas and therefore should have been suitable Florida scrub-jay habitat (Breininger personal observation, Duncan and others unpublished data). Only about 1/2 of the potential habitat is protected if one assumed a recovery goal was to recover scrub-jay populations to the maximum extent possible without including suburban jays that seem to have poor long-term persistence probabilities (Stith et al. 1996, Breininger 1999, Bowman unpublished, Stith 1999). Almost half the potential territories within PRUs have not even been proposed by a conservation land acquisition organization for protection. Some of these include landscapes of scrub and flatwoods that are contiguous for >5.0 kilometers (e.g., north of Buck lake, south of Fellsmere Road.

Except for Central Brevard, these metapopulations have some of the greatest potential within the range of the Florida scrub-jay (Stith 1999). Much additional habitat protection is needed to reduce extinction risk (Root 1998, Breininger et al. 1999a, Stith 1999). Separated and greatly reduced metapopulations might be vulnerable to inbreeding and the reduction of genetic information necessary for adaptation and resistance to new threats. A new threat, for example, includes the introduced West Nile Virus.

Additional mitigation and habitat acquisition efforts need to focus on making subpopulations larger and enhancing the connectivity between metapopulations. These also should focus on reducing edge/area ratios, which do not influence Florida scrub-jay population viability (see Mumme et al. 1991, Bowman and Woolfenden 2001) but are also critical to consider for other species (Breininger et al. in press). Several potentially large PRUs need to be incorporated into land acquisition plans. Developing a plan for conservation is complicated by economics and the willingness of sellers (of land). Recovery planning must be opportunistic by setting targets for overall population size and arrangement that are flexible enough to be implemented on a regional scale where there is political resistance to growth management and land use planning specific to maintaining viable populations. The relevance of each PRU is described in Section 6.

Habitat Quality of Potential Territories.

Habitat quality of most potential territories was poor because tree densities had become too great or because shrubs had become too tall. These changes were becoming common by the 1960s as natural and prescribed fire (by ranchers) frequencies were reduced because of urbanization and fire suppression (Duncan et al. 1999, in press). Habitat quality was already poor by 1992 and probably had been poor for decades (Swain et al. 1995, Boyle 1996). Populations presumably have been declining for decades based on habitat quality and habitat-specific demographic data collected elsewhere (Woolfenden and Fitzpatrick 1991, Root 1998, Breininger et al. 1999a). Many conservation areas showed progress in restoring habitat, but most still were suboptimal in 2002, because restoration is often a slow process (Schmalzer and Boyle 1998, Breininger and Carter 2003).

Habitat quality was generally worst in North Brevard because of a longer history of fire exclusion. Much scrub was still ranchland in Central and South Brevard during the 1970s and ranchers frequently used prescribed fire. Extensive fuels loads were reduced by 1998 wildfire in North Brevard, but these occurred in a region (Buck Lake and North) where Florida scrub-jay populations had declined to only a few pairs. Primary territories had a greater tendency to be tall with too many trees compared to secondary and tertiary territories because they do not burn as readily as palmetto-dominated habitats (Breininger et al. 2002). Primary territories should have had greatest propensities to be optimal, instead of short, if fire regimes were frequent (Breininger and Oddy unpublished manuscript).

Potential territories along roads tended to have the poor habitat quality not only because small habitat fragments have a lower propensity to burn (Duncan and Schmalzer unpublished) but also because edges themselves burn poorly (Breininger et al. 2002).

Population Size

Population declines were much greater than the rates of habitat loss, as expected because of poor habitat quality. The differences between actual population size and potential population size was probably greatest in North Brevard because habitat quality was the poorest and this probably occurred for the longest period because so many potential territories were tall and forested. Unless scrub has remained unburned for long periods, it takes an average of 20 years to become suboptimal and much longer to become forested (Schmalzer et al. 1994).

We do not know why population declines did not appear in Central Brevard between 1992 and 2002. One possibility was that 1992 populations were underestimated and another possibility is that habitat quality actually improved between 1992 and 1999. Habitat quality was generally poor in 1992 (Swain et al. 1995, Boyle 1998) but wildfires and habitat management at the Viera mitigation site caused improvements. Site-specific descriptions of population size changes are provided elsewhere (Brevard County Natural Resources Department 2002).

4.0 Demography and Dispersal of Florida Scrub-Jays on the Mainland of Central Florida's Atlantic Coast.

The focus was to classify actual territories based on their habitat characteristics and quantify their demography. The quantification of habitat-specific demography is critical for understanding how habitat arrangements influence population dynamics and for developing population management strategies (Pulliam et al. 1992). We focus on the territory scale because these are the most basic landscape unit for quantifying habitat-specific population processes (Breininger and Carter 2003). We compare habitat potential of primary, secondary, and tertiary territories described in Chapter 3 to evaluate the potential contributions of palmetto-oak to Florida scrub-jay populations. We evaluate whether the edges of conservation reserves are likely to be population sinks, which would suggest extirpation of all populations, except in the largest reserves. We test rapid habitat assessment procedures that might explain the population decline and be used to determine prescribed fire management needs. We do not use our more detailed habitat suitability index model (Duncan et al. 1995, Breininger et al. 1998) because it is cumbersome for managers to implement, especially given the uncertainties (Burgman et al. 2001). We also quantify dispersal patterns and exchanges among territory clusters that we observed.

4.1 Methods

Study Sites. On the mainland, colorbanding began during 1997 in South Brevard because most Florida Scrub-Jays and protected areas occurred there. We expanded study sites as areas were acquired for conservation allowing us to obtain access for the following investigations. A Florida Fire Science Team was formed to address questions that remained following the large 1998 wildfires. This team funded our initial expansion into North Brevard (Breininger et al. 2001). In 2000, we expanded into Central Brevard because of rapid habitat destruction and concerns by the U.S. Fish and Wildlife Service and recovery team biologists. The study ended prematurely after July 2002 because of funding. Figure 17 and Table 7 summarize the locations of territory mapping, demography, and dispersal studies involving color-banded Florida Scrub-Jays. We did not perform demography studies at Hollywood and Pirates territory clusters, although territory boundaries were provided. To quantify population size and dispersal into study tracts, we banded Florida Scrub-Jays at many sites where we did not perform territory mapping or demography studies (e.g., Port St John, East Micco, and Wabasso). Previous sections described that surveys for dispersed jays were conducted throughout 85% of the metapopulation.

Table 7. Number of Florida scrub-jay territories investigated on the mainland of Brevard County and Indian River County.

Territory Cluster	1997	1998	1999	2000	2001	2002
Buck Lake	0	0	3	2	2	2
Seminole Ranch	0	0	0	11	8	7
Tico-Grissom	0	0	0	16	20	17
Viera	0	0	0	1	18	14
Wickam	0	0	0	10	17	17
Malabar-Jordan-Valkaria	35	25	28	33	33	43
Stewart	0	0	0	0	4	4
Palm Bay	26	17	13	18	20	19
West Micco	13	11	9	9	10	11
Sebastian	3	3	3	16	14	14
Fellsmere	5	5	6	4	31	32
Totals	82	61	62	120	177	180

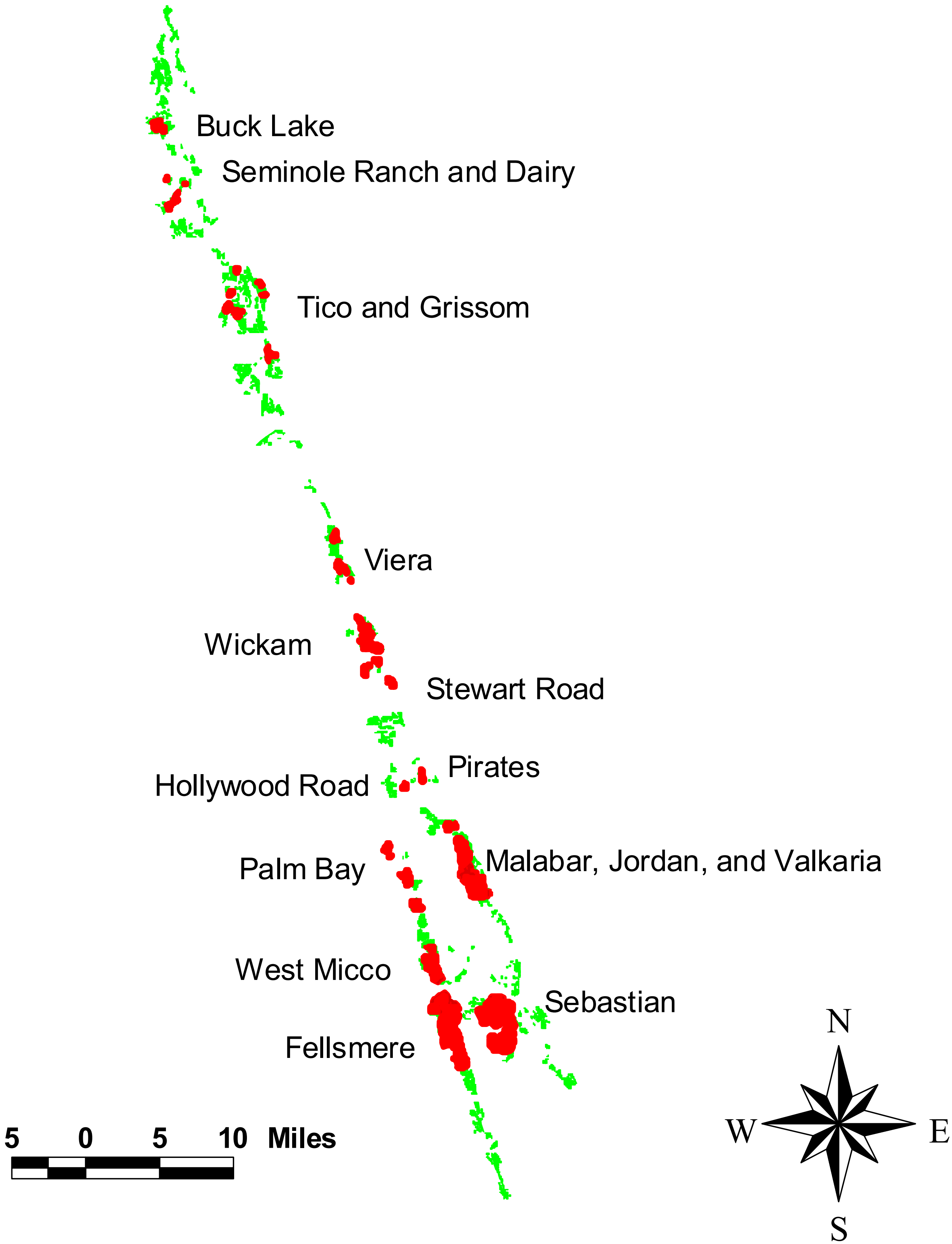
Capture, colorbanding, and census. For each new study area, we repeatedly surveyed the site 2-7 days each week to quantify the number of Florida scrub-jay territories and individuals occupying the site. During this time, we exposed Scrub-Jays to raw peanut bits to prepare them for capture. Once jays became familiar with peanuts, we baited Potter traps but kept the trap doors wired open. Once many jays entered traps, we began the capture process. In addition to Potter traps, we used drop traps to capture jays unwilling to enter Potter traps. Mist nets were also used to capture jays unwilling to enter either trap. Captured jays were banded with a unique combination of one silver and 2-3 colorbands. Once captured, covert feathers were examined to distinguish individuals less than one-year-old from older jays. We attempted to capture every jay providing we had access to its territory. Unbanded jays remained at most sites because they were difficult to capture or because we could not obtain permanent access. Conservation often involved partial acquisition of potential habitat within landscapes and this influenced our access. Access improved during the study as more land was acquired.

Throughout the study we color-banded juveniles and immigrants. We had difficulties capturing many individuals on several sites so that some demographic analyses (e.g., survival) involved samples of the population at those sites and not complete demographic analyses of every territory. Most Florida Scrub-Jays were color-banded at a site before we began quantifying survival at the site. Breeders were identified based on dominance behaviors, intensity of territory defense, and nesting activities (Woolfenden and Fitzpatrick 1984, 1991, 1996: Breininger et al. 1996a; Breininger 1999). Our efforts were to focus on banding as many jays in as many territories as possible, rather than conducting the intensive systematic nest searches sometimes performed. Juveniles were tallied among all territories in July. We sometimes quantified juvenile production before most individuals were color-banded because juveniles in July were conspicuous and nearly always could be found with their families.

Territory mapping. Territory mapping was conducted from April through May. Normally, boundaries were delineated to within a few meters by initiating disputes between families (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995). All published studies have involved areas where all scrub was rigorously contested and occupied by jays (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995, 1998). In this study, territory disputes did not occur in some large expanses of mesic flatwoods, extensively burned areas, forests, agricultural areas, or urban areas that were adjacent to areas occupied by Florida Scrub-Jays. Areas of unoccupied suitable habitat often occurred adjacent to occupied territories. In these cases, we mapped boundaries based on areas where jays appeared unwilling to enter. Territory boundaries for every year were digitized as ARC/INFO polygon files. The primary purpose of these boundaries was to characterize habitat quality at the territory scale. We did not focus our analyses on territory size because Florida Scrub-Jays used much larger areas than they need because population sizes were far below carrying capacity in most areas.

Territory quality. Oak cover and proximity to human edges represented habitat potential; height arrangements represented current habitat suitability and were influenced by fire history. Oak cover in territories was classified as primary if the territory intersected $\geq$0.4 ha of oak scrub on well-drained soils (Breininger and Oddy 2001). We used U.S. Department of Agriculture soils maps (Huckle et al. 1974, Wettstein et al. 1984) to define well-drained soils. Territories were designated secondary if they did not intersect well-drained oak scrub but intersected scrub oak polygons having > 50% scrub oak cover but $\geq$0.4 ha. Territories were designated tertiary if they lacked any oak scrub polygons > 0.4 ha in size that had > 50% oak cover. We classified territories into three categories based on their context to human-dominated landscapes. "Core" territories were not adjacent to human housing or hard surface roads. "Edge" territories were within potential reserves and bordered human landscapes, but were not adjacent to hard surface roads. "Suburban territories" occurred within suburban areas or were adjacent to hard surface roads. Height was classified using criteria in Table 3 derived from long-term studies at KSC (Breininger and Carter 2003).

Figure 17. Locations of Florida scrub-jay territories that were mapped in 2001 or 2002. Florida Scrub-Jays were also colorbanded in many other locations.



Analyses. Individual study years were from 1 April to 31 March. The demographic study funded by the U. S. Fish and Wildlife Service ended in July 2002 because of funding cuts. We did not separate the 1997 epidemic year from other years because we no longer assumed epidemics were rare annual events (see Woolfenden and Fitzpatrick 1984). West Nile Virus is a new potential disease that could be common and widespread, as confirmed in sentinel chickens with Brevard County and Indian River County during the summer of 2002. Related studies in 2002 suggest that survival of Brevard and Indian River county Scrub-Jays was greatly reduced by this new disease.

Continuities of pair-bonds between successive breeding seasons were compiled for all years for pairs where both breeders were colorbanded. Four categories were used to describe changes in pair-bonds between breeding seasons: one breeder paired with another Florida Scrub-Jay after the death of its spouse in the same territory; one breeder became a nonbreeder after the death of its spouse; mortality of both breeders; and divorce (Breininger et al. 1996a, Breininger 1999).

We calculated the mean distance between natal and breeding destination territories for males and females (see Woolfenden and Fitzpatrick 1984). We also developed a dispersal curve that was based on the number of territories that occurred between the natal territory and the territory where jays first bred. This was produced was by establishing a straight line between natal and breeding destination territories and then counting the actual territories that intersected the line. We compiled all data on Florida Scrub-Jays having a known history since hatching to quantify the frequency that one-year-old jays delayed breeding.

We defined juveniles as young Florida Scrub-Jays present in July when most of them approached nutritional independence (Woolfenden and Fitzpatrick 1984). For each year, the number of juveniles and yearlings produced per breeding pair was calculated in every territory.

Annual survival for helpers and breeders was calculated as the number of jays that survived during a study year divided by the number alive at the beginning of the study year (Woolfenden and Fitzpatrick 1984, 1996; Breininger et al. 1995, 1996a, 1998a). We calculated birds as having survived if they were seen anytime after the annual survival period ending date. Survival analyses were performed only on colorbanded individuals. Bowman (unpublished report) compared these approaches with mark-recapture models and determined that breeder survival analyses produced identical results but that the above approaches produced slight, but insignificantly lower, nonbreeder survival rates. We didn’t perform mark recapture analyses because our mean monthly detection probabilities exceeded 0.9 and so that our apparent survival estimates approached true survival estimates, excluding permanent and undetected emigration. To investigate potential errors we tallied all birds that were known to be alive but that were not observed for an entire year. We also tallied all jays known to have emigrated but that would not have been known to survive had we not been surveying most of the population on a regular basis. Extensive peripheral surveys allowed us to observe most successful offsite dispersals because we surveyed >85% of the population. We will investigate these small errors more extensively using multi-state models (Williams et al. 2001) and other approaches (e.g., Koenig et al. 2000) as we prepare results for journal publication.

We calculated demographic performance for every year in every territory within our study area by subtracting the number of breeders that died from the number of yearlings that were produced (Breininger et al. 1995, 1998). Demographic performance was calculated only for pairs where both breeders were colorbanded. We assumed that our samples approximated independent observations because there was more than normal annual breeder turnover, because individual territories often varied among treatment categories (e.g., breeder experience, presence/absence of helpers), because there was much annual variation in spatial distributions of habitat suitability, and because there was annual variation in environmental factors (e.g., rainfall) and population density. Furthermore, study site expansions allowed us to increasingly sample a larger portion of the actual population so that new pairs were continuously being added into the sample and we studied a large proportion of the population.

We used one-sample Kolmogorov-Smirnoff tests to determine whether data differed from a normal distribution. If they differed significantly ($p < 0.05$), we used nonparametric Mann Whitney U exact tests for two treatment tests and Kruskal-Wallis exact tests for multiple treatment tests (SPSS 1999). We also used ANOVAs (SPSS 1999) to test whether means varied among treatments (habitat types, presence of helpers). When assumptions regarding normality and the homogeneity of variance were violated, we still focused our presentation on the parametric ANOVAs, providing the conclusions regarding the results of statistical significance were the same ($p < 0.05$) with the nonparametric tests. We used parametric analyses of variances because they tend to be robust to deviations from normality and homogeneity of variances and we wanted to perform pair-wise comparisons. Providing the means were significantly different, pair-wise comparisons were performed using Tukey's tests when variances were homogeneous. We used the Games-Howell tests when variances were not equal (SPSS 1999). Differences in breeder survival among treatments categories were tested using likelihood ratio exact tests.

More complex analyses will be performed on a set of alternative general linear models to test for interactions among variables as the data is prepared for scientific journal publication. We chose to avoid such analyses in this report in order to avoid the negative consequences of data dredging and because preliminary analyses revealed that limited sample sizes for optimal territories greatly limited the management utility of multivariate analyses. Sample sizes for optimal territories were only beginning to become sufficient for investigating multivariate relationships prior to termination of the study. A slow accumulation of optimal territories across a range of other habitat factors occurred because there were few optimal territories in public ownership when the studies began. The number of optimal territories increased slowly because there was a lag between the time habitat became optimal after land acquisition because of vegetation response to fire and the logistical difficulties associated with restoration (Breininger and Carter 2003).

4.2 Results

We color-banded 800 Florida Scrub-Jays and studied demography of 180 Florida scrub-jay territories during 2002, which represented approximately 64% of the combined North Brevard, Central Brevard, and South Brevard-Indian River-St. Lucie metapopulations. We present 2 examples to demonstrate the dynamics of habitat occupancy and territory shifts. The first example shows that the amount of habitat occupied can change greatly across years and that Florida Scrub-Jays were not restricted to xeric oak scrub (Figure 18). In this example, all palmetto-oak territories were almost always occupied but xeric oak territories were often not occupied because they did not burn enough or they burned too extensively. The second example shows an example of variation between years (Figure 19). None of the examples were unusual for the data set.

Basic Demography. Of pair bonds where both breeders were color-banded, 61% stayed together between successive years, 23% involved the death of one breeder and the survivor finding a replacement breeder, 11% involved the death of both breeders, 4% involved the death of one breeder with the survivor becoming a non-breeder, and 1% resulted in divorce. The respective probabilities that individual breeders bred, helped, or floated during the next year were 0.97, 0.02, and 0.01 for breeders that survived the year (n= 754).

Mean family size during the study was 2.77 adults (n = 682). The respective probabilities that helpers bred, helped, or floated during the next year were 0.36, 0.62, and 0.02 for helpers that survived to the following year (n= 254). Sixty-five percent of female one-year-olds (n= 101) helped during the first nesting season after hatching. Seventy-nine percent of male one-year-olds (n=136) helped during the first nesting season after hatching. Sex-specific differences in the frequency of helping by one-year-olds were significant (log likelihood ratio value = .023; P = 5.185).

A total of 312 color-banded jays permanently disappeared. There were 7 Florida Scrub-Jays that disappeared for >1 year and were later re-sighted. These included 3 breeders, 3 juveniles, and 1 helper. Only 2 of these did not move to another territory cluster. Only 6 breeders were observed to move from the cluster where they were observed to have first bred. Only 3 one-year olds moved to a territory cluster that was different than their natal cluster. Thirteen helpers moved to another territory cluster.

There was much annual variation in demography (Table 8). Female breeder survival was 0.75 (n = 285) and male breeder survival was 0.76 (n = 331); these differences were not significant (log likelihood ratio value = .151; P = 0.768). Female helper survival was 0.76 (n = 106) and male helper survival was 0.73 (103) these differences were not significant (log likelihood ratio value = .361; P = 0.548).

Juvenile production was 0.94 (n = 190) for experienced breeders and 0.52 (n = 56) for novice breeders; these differences were significant (F = 4.527; P = 0.034). Yearling production was 0.58 (n = 111) for experienced breeders and 0.40 (n = 40) for novice breeders; the P value for these differences was 0.305 (F = 1.061). Survival of experienced breeders was 0.81 (n = 303), and survival of novice breeders was 0.73 (n = 86); the P value for these differences was 0.134 (log likelihood ratio value = 2.248).

Demographic performance was 0.23 (n = 108) for experienced breeders and -0.26 (n = 38) for novice breeders; these differences were significant (F = 4.659; p = 0.033).

Juvenile production was 0.94 (n = 335) for breeders with helpers and 0.66 (n = 347) for pairs without helpers; these differences were significant (F = 8. 593; P = 0.004). Yearling production was 0.56 (n = 240) for breeders with helpers and 0.42 (n = 255) for pairs without helpers; the P value for these differences was 0.094 (F = 2.807). Survival was 0.80 for breeders with helpers and 0.72 for breeders without helpers; these differences were significant (F = 6.020; P = 0.014). Demographic performance was 0.214 (n = 135) for pair with helpers and -0.13 (n = 127) for pairs without helpers; these differences were significant (F = 5.342; P = 0.022).

Demography and Habitat Arrangements. A large number of territories occurred in palmetto-oak even and most territories not located along xeric oak scrub (primary ridges) occurred in secondary territories (Table 9). Secondary territories did not have lower demographic success than primary territories; tertiary territories were population sinks.

Table 8. Annual variation in demography and comparison with other published studies

Location	Year	Juveniles /pair	Yearlings /pair	Demographic performance	Breeder Survival	Helper Survival
Brevard Mainland	1997	0.83	0.39	-0.82	0.51	0.77
Brevard Mainland	1998	0.65	0.36	-0.09	0.73	0.78
Brevard Mainland	1999	1.75	0.80	0.35	0.72	0.75
Brevard Mainland	2000	0.74	0.32	-0.05	0.77	0.68
Brevard Mainland	2001	0.82	0.59	0.20	0.83	0.77
Brevard Mainland	2002	0.52	N/a	N/a	N/a	N/A
Mean of Annual Means		0.89	0.49	-0.08	0.71	0.75
South Brevard Beaches [a]	1993-1997	0.41	0.22	Not reported	0.73	0.48
Happy Creek at KSC [b]	1989-1993	0.47	0.32	Not reported	0.80	0.73
Tel 4 at KSC [b]	1988-1993	0.96	0.62	Not reported	0.76	0.72
Optimal Scrub at Archbold [c]	1969-1986	1.23	0.68	Not reported	0.81	0.74
Tall Scrub at Archbold [d]	1969-1986	0.80	0.36	Not reported	0.72	Not reported

[a] Breininger (1999).
[b] Breininger et al. 1996a
[c] Woolfenden and Fitzpatrick 1984
[d] Woolfenden and Fitzpatrick 1991

Figure 18. Comparison of Occupied Territories at Valkaria.

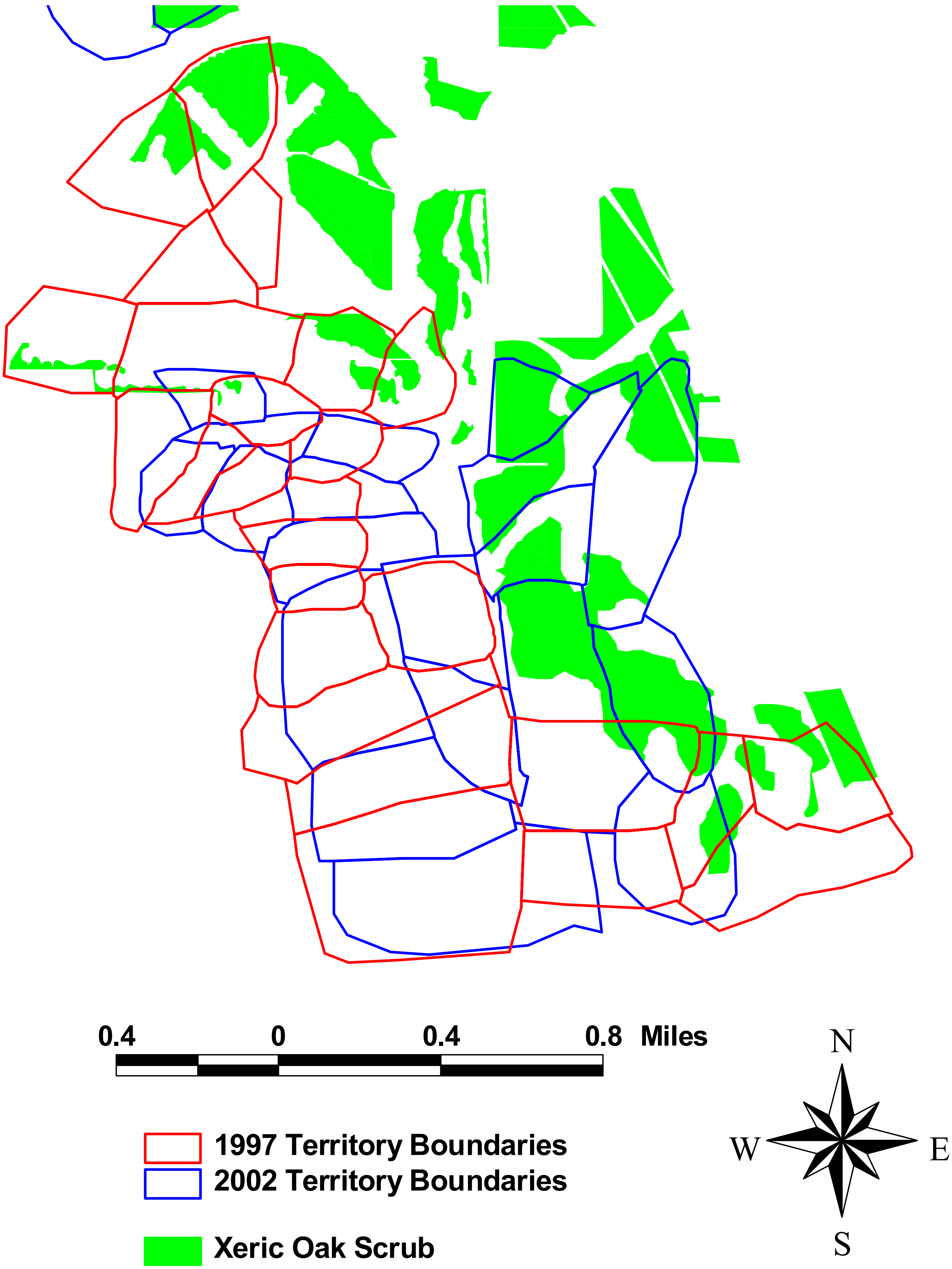
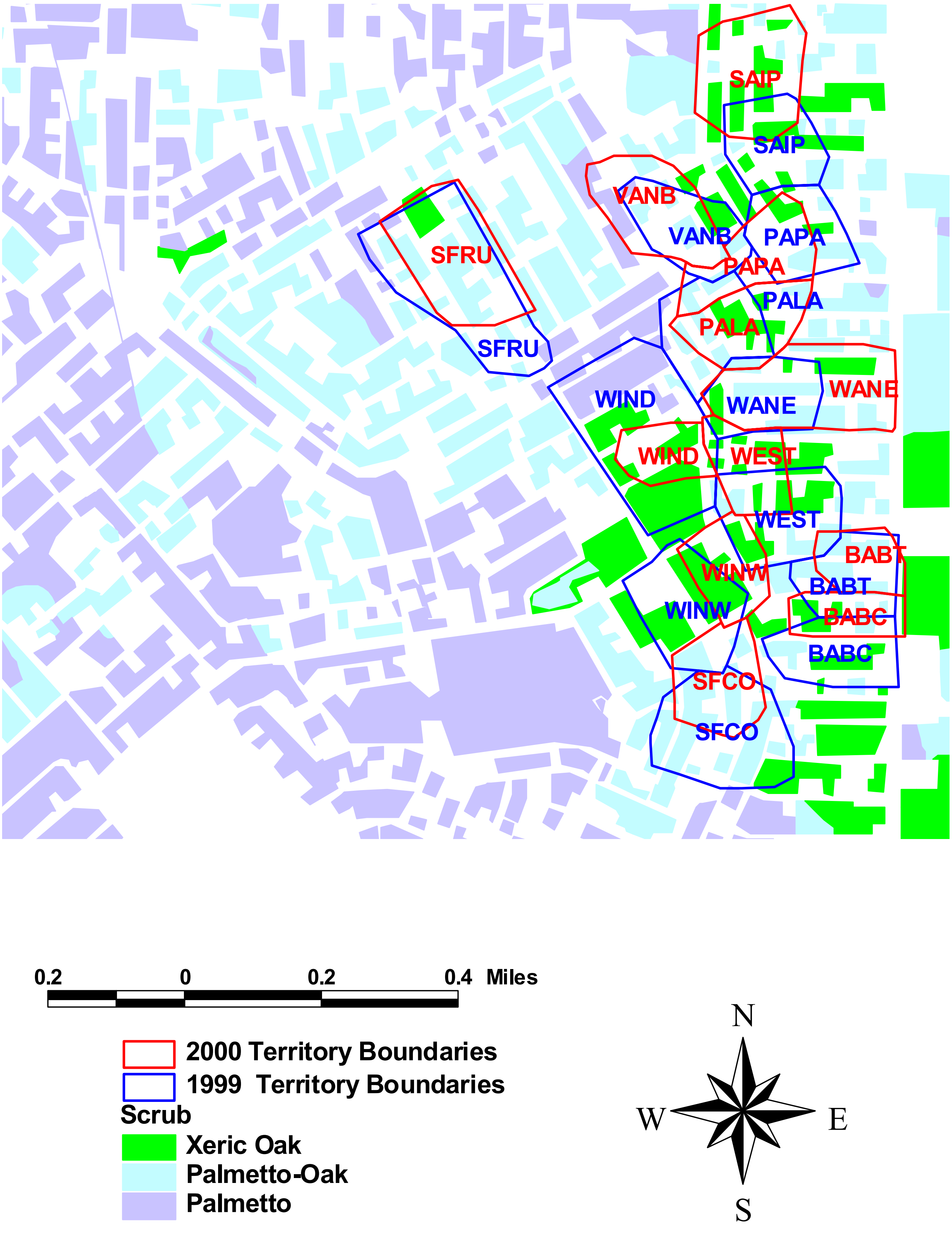


Figure 19. Comparison of Occupied Territories at Palm Bay.



Caption 9. Juvenile Florida Scrub-Jays showing brown head and silver tips on coverts.

Table 9. Demography among territories having different scrub oak cover.

	Type of scrub (mean ± standard error; sample sizes in parentheses)			Statistics	
	Primary [a]	Secondary [b]	Tertiary [c]	ANOVA (F)	P
Juvenile Production (pairs)	0.85 ± 0.06 (432)	0.75 ± 0.08 (213)	0.43 ± 0.12 (37)	2.235	0.108
Yearling Production (pairs)	0.51 ± 0.06 (309)	0.47 ± 0.81 (161)	0.32 ± 0.12 (25)	0.562	0.571
Demographic Performance (pairs)	-0.02 ± 0.09 [e, f] (162)	0.26 ± 0.12 [e] (86)	-0.50 ± 0.27 [f] (14)	3.070	0.048
Breeder Survival	0.73 ± 0.02 (381)	0.84 ± 0.03 (207)	0.59 ± 0.09 (27)	12.635 [d]	0.002

[a] = xeric oak scrub.

[b] = palmetto-oak with patches of oak scrub ≥0.4 ha and no xeric oak scrub.

[c] = palmetto-oak with no patches of oak scrub >0.4 ha and no xeric oak scrub.

[d] = Log likelihood test value; ANOVA not performed on breeder survival.

[e,f] = Post Hoc analyses suggested these were not significantly different p >0.05.

Proximity of territories to human landscapes was not a good predictor of demographic success when other habitat factors were not considered (Table 10). The arrangement of shrub height within territories was the most important predictor of demographic success (Table 11). Sample sizes were low for short territories during all years. Sample sizes were also low for optimal territories, except during 2001 and 2002. Only optimal scrub produced an excess of potential breeders. Although sample sizes were too low to draw conclusions, reserve edges did not appear to be population sinks if habitat conditions approached optimal (Table 12). We just began accumulating samples to investigate the influence of human landscape context in territories with optimal height arrangements when funding expired.

Table 10. Demography among territories having different attributes of human landcover.

	Type of scrub (mean ± standard error; sample sizes in parentheses)			Statistics	
	Core [a]	Reserve Edges [b]	Suburbs [c]	ANOVA (*F*)	*P*
Juvenile Production	0.88 ± 0.08 (277)	0.90 ± 0.13 (108)	0.69 ± 0. 60 (297)	2.195	0.112
Yearling Production	0.58 ± 0.07 (187)	0.59 ± 0.10 (80)	0.38 ± 0.06 (228)	2.984	0.052
Demographic Performance	-0.06 ± 0.13 (104)	0.27 ± 0.18 (51)	-0.08 ± 0.10 (107)	1.553	0.214
Breeder Survival	0.74 ± 0.03 (232)	0.79 ± 0.04 (112)	0.76 ± 0.03 (271)	1.439 [d]	0.487

[a] = not adjacent to human-dominated landscapes.

[b] = in potential reserves but adjacent to human-dominated landscapes but not hard surface roads.

[c] = surrounded by human landcover types or bordering hard surface roads.

[d] = log likelihood test value; ANOVA not performed on breeder survival.

Table 11. Demography among territories having different fire history (shrub height arrangements).

	Type of scrub (mean ± standard error; sample sizes in parentheses)				Statistics	
	All Short [a]	Optimal [b]	Tall Mix [c]	All Tall [d]	ANOVA (F)	P
Juvenile Production	0.70 ± 0.40 (10) [f,g]	1.35 ± 0.14 (121) [f]	0.70 ± 0.06 (367) [f,g]	0.64± 0.08 (184) [g]	10.173	0.000
Yearling Production	0.22 ± 0.22 (9) [f]	1.17 ± 0.18 (64)	0.46 ± 0.05 (274) [f]	0. 26 ± 0.05 (148) [f]	16.296	0.000
Demographic Performance	-0.38 ± 0.26 (8) [f]	0.82 ± 0.22 (38)	0.03 ± 0.11 (144) [f]	-0.30 ± 0.113 (72) [f]	8.172	0.000
Breeder Survival	0.69 ± 0.12 (16)	0.88 ± 0.03 (88)	0.76 ± 0.02 (334)	0.71 ± 0.03 (177)	9.949 [e]	0.019

[a] = entire territory was < 120 cm tall except for scattered trees and shrubs.

[b] = entire territory < 170 cm tall except for scattered trees and shrubs and at least 0.13 ha oak at 120-170 cm tall among short scrub .

[c] = territory included at least 0.4 ha of tall shrubs (170 cm) among shorter shrubs.

[d] = entire territory was > 170 cm tall except for some shrubs.

[e] = log likelihood test value; ANOVA not performed on breeder survival.

[f,g] = Post Hoc analyses reveal that these are not significantly different p <0.05.

Caption 10. Example of another secondary ridge.

Table 12. Demography among primary and secondary territories having optimal height but different attributes of human landcover.
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	Type of scrub (mean + standard error; sample sizes in parentheses)			Statistics	
	Core [a]	Reserve Edges [b]	Suburbs [c]	ANOVA (F)	P
Juvenile Production	1.40 + 0.15 (81)	1.54 + 0.53 (13)	1.11 + 0.34 (27)	0.458	0.634
Yearling Production	1.25 + 0.18 (40)	1.25 + 0.41 (8)	0.94 + 0.52 (16)	0.279	0.757
Demographic Performance	0.83 + 0.27 (24)	1.43 + 0.43 (7)	0.14 + 0.51 (7)	1.696	0.198
Breeder Survival	0. 86 + 0.05 (57)	1.00 + 0.00 (12)	0.84 + 0.08 (19)	3. 499 [d]	0.174

[a] = not adjacent to human-dominated landscapes.

[b] = in potential reserves but adjacent to human-dominated landscapes but not hard surface roads.

[c] = surrounded by human landcover types or bordering hard surface roads.

[d] = log likelihood test value; ANOVA not performed on breeder survival.

Caption 11. Florida scrub-jay nest are often concealed in myrtle oaks (*Quercus myrtifolia*) with an outer structure of twigs and an inner lining of fibers pulled off cabbage palms (*Serenoa repens*).

Dispersal. Mean natal dispersal distances were 1.0 km (n = 56) for males and 2.8 km for females (n = 65); these differences were significant (p = 0.010). The longest distance dispersals were 31 km for females and 13 km for males. Ninety-five percent of all male and 92% of all female natal dispersal traversed only 7 territories (Figure 9). Florida Scrub-Jays from the same territory cluster filled 91% of breeding vacancies that were filled by color-banded birds. We observed movements between most subpopulations in South Brevard (Table 13). Three exchanges between Central and South Brevard metapopulations were observed but no exchanges were observed between the North Brevard metapopulation Central or South Brevard metapopulations. Scrub-Jays that immigrated into the study tracts from unknown locations. Twelve of these immigrants from unknown locations became residents at Valkaria and half of all the immigrants were one-year-olds. We were unable to colorband many Florida Scrub-Jays inhabiting several study sites so that 5-20 unbanded immigrants filled vacancies. Only one Florida scrub-jay, colorbanded in our study sites, was found in a habitat fragment outside of our study sites during our peripheral surveys. The remaining exchanges occurred within our study sites.

Figure 20. Mean Dispersal Distance Between the Natal Territory and the Territory Where a Florida Scrub-Jay First Became a Breeder.

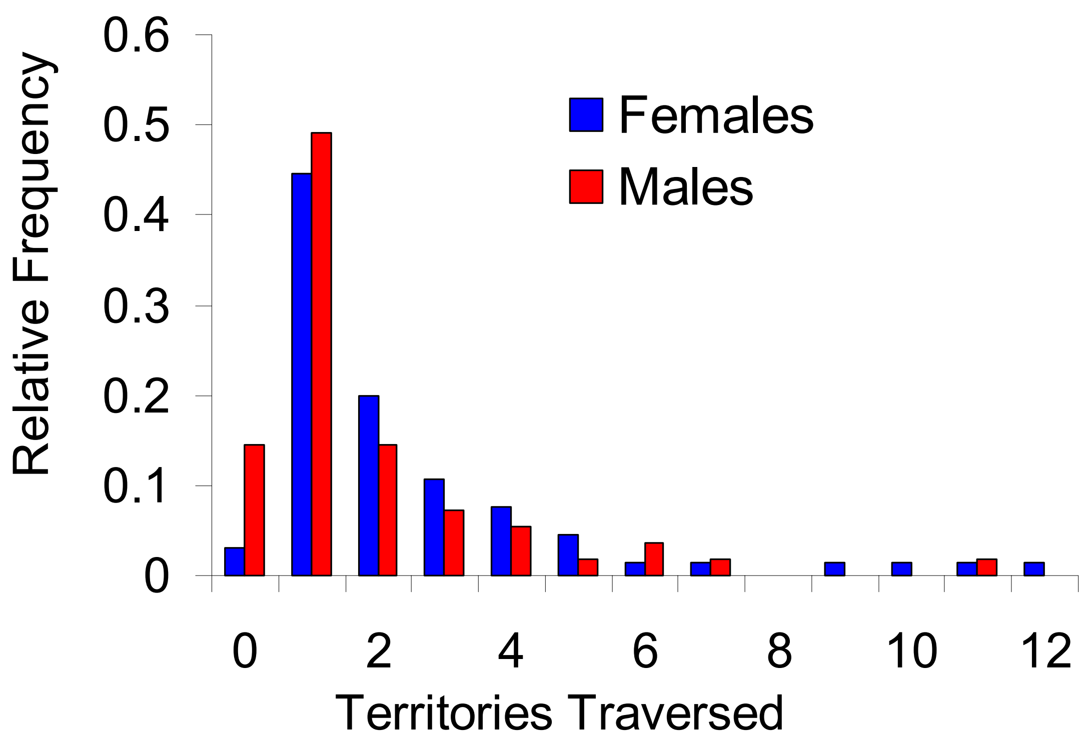


Table 13. Exchanges of Florida Scrub-Jays Among Territory Clusters.

	Destination Cluster								
Cluster of Origin	Viera	Wickam	Stewart	Melbourne Airport	Malabar-Jordan-Valkaria	Palm Bay	West Micco	Sebastian	Fellsmere
Viera									
Wickam									
Stewart									
Melbourne Airport		1							
Malabar-Jordan-Valkaria		3					1	1	1
Palm Bay					1				1
West Micco					3			1	3
Sebastian						1			2
Fellsmere							3	1	

Notes: Entries are the number of individuals

Caption 12. Optimal primary ridge (xeric oak scrub).

4.3 Discussion

Basic Demography. By 2001, demographic studies sampled 64% of the combined metapopulations of North Brevard, Central Brevard, and South Brevard-Indian River-St. Lucie. Sample sizes for survival and demographic performance were smaller because of difficulties in capturing all birds. We estimate that approximately 85% of territories were surveyed for dispersed individuals during 2001-2002. Surveys by us, U. S. Fish and Wildlife Service personnel, Brevard County and Indian River County government employees, consultants, and interested citizens suggested that few jays from our demographic study tracts successfully became breeders outside our study tract without our detection.

We estimated a 34% decline in the number of breeding pairs between 1992 and 2002 in Section 3.0. Population models based on demographic data collected from elsewhere and applied to habitat quality associated with the population studied here predicted a population decline of 40% per decade (Breininger et al. 1996b, Root 1998, Breininger 1999). All demographic variables were below levels associated with optimal habitat needed to sustain the populations (Woolfenden and Fitzpatrick 1984, 1991; Breininger et al. 1999a). Based on habitat quality and the extent of overgrown scrub in 1992 (Swain et al. 1995, Boyle 1996), it was reasonable to assume that the population declined by 30-50% a decade for at least 1-2 decades before 1992 without even considering the effects of habitat loss. Similar declines were associated with the federal properties (Breininger et al. 1996b).

Results of pair bond fidelity were similar to other published studies (Woolfenden and Fitzpatrick 1984, Breininger et al. 1996a. The frequency of both breeders dying during the same year was higher in this study because of the low survival associated with the presumed epidemic that occurred in 1997 (Breininger et al. 1999b). Rates of breeding by one-year-olds were much greater than associated with stable populations where breeding vacancies are scarce (i.e., Woolfenden and Fitzpatrick 1984). Higher rates of delayed breeding have been reported before in declining populations and delayed breeding appears directly related to breeding opportunities (e.g., Breininger et al. 1996a, Breininger 1999).

Mean family size was lower than typical for optimal habitat (Woolfenden and Fitzpatrick 1984). Increased breeding opportunities for nonbreeders occurred because mortality exceeded reproductive success and because the amount of suitable habitat increased from habitat restoration and wildfires in many areas. Habitat restoration can increase breeding opportunities as was evident by many one-year-olds that bred at restored sites at Valkaria and Sebastian Buffer Reserve.

There was much suitable but vacant habitat and a surplus of potential breeders (helpers) indicating that nonbreeders did not distribute themselves in proportion to the breeding opportunities that existed. Although much vacant habitat was marginal, there were many vacant optimal territories at Valkaria, Micco, Babcock, and north Sebastian Buffer Reserve. Helpers might choose to not disperse into suboptimal habitats but this does not explain vacant optimal territories. There are many possible explanations about why territories that recently became optimal were unoccupied for periods of time. These optimal territories were rarely adjacent to territories with helpers and were rarely near territories with helpers. Low dispersal propensities by males and conspecific attraction were two explanations. Conspecific attraction might be important because jays from many territories provide greater vigilance against predators. Florida Scrub-Jays have a sentinel system keenly adapted to detecting accipiters (McGowan and Woolfenden 1989), which are always common along the Atlantic coast (Breininger et al. 1996a, authors personnel observations). Another explanation for unoccupied territories was that many helpers were closely related within fragments, and Florida Scrub-Jays have tendencies to avoid incest (Woolfenden and Fitzpatrick 1984). We plan to use an information-theoretic approach to test alternative models as the data is prepared for journal publication. Practical applications of these results are that attempts should be made to prevent extinction within PRUs that already have jays and prioritize restoration near territories that have helpers.

There is little data so far on Florida Scrub-Jay population responses to restoration across a broad range of conditions. Population modeling also suggested that providing opportunities for enhancing the survival of existing Florida scrub-jays and providing breeding opportunities for helpers were important because population expansion attributed to reproductive success exceeding mortality could be a slow process (Breininger et al. 1999a). This occurs partially because experienced breeders and breeders with helpers have greater demographic success than novice breeders and breeders without helpers (also see Woolfenden and Fitzpatrick 1984, 1996). Recently colonized areas tended to be inhabited by inexperienced jays. Delays in the saturation of restored areas might occur because it takes years for experienced breeders and nonbreeders to accumulate (Breininger et al. 1999aa).

Demography and Habitat Arrangements. The results were consistent with long-term studies on KSC where primary and secondary territories functioned as population sources when habitat was optimal; tertiary territories were population sinks (Breininger and Oddy 2001). Here, population sources refer to areas that produce an excess of potential breeders and emigration that exceeds immigration. These should not be confused with habitat fragments that have mortality that exceeds reproductive success but supply immigrants to other areas, such as larger habitat fragments (Breininger 1999, Bowman unpublished). Suburban areas provide an example of the latter where dispersal has been one-way: from suburbs into natural landscapes (Thaxton and Hingtgen 1996; Bowman unpublished). This latter process can only be sustained as long as suburbs have immigrants to supply. Here, population sinks refer to areas with mortality that exceeds reproductive success that can only be sustained by immigration, which exceeds emigration.

In this study, most primary territories had too much tall scrub. Oak scrub does not burn as readily as palmetto-dominated scrub (Breininger et al. 2002). Secondary territories often have greater habitat quality than oak-dominated areas because they burned more readily. This study showed that not only does palmetto-oak provide for an overall larger population but palmetto-oak in optimal condition serves as a population source. Although much xeric oak scrub was unoccupied because it was overgrown, xeric oak can contribute most to recovery once restored because territory quality generally increases as oak cover increases if other habitat conditions are not suboptimal (e.g., Breininger et al. 1995, Grubb et al. 1998, Breininger and Oddy unpublished manuscript). Although this study was too short with too few optimal territories to compare dispersal propensities among source and destination territories, we did observe many movements from optimal to suboptimal territories. We demonstrated such source-sink dynamics within landscapes elsewhere (Breininger and Oddy 2001, Breininger and Carter 2003).

Results suggested that territories enclosed within suburbs and along roads had mortality that exceeded reproductive success, which was consistent with other studies (Breininger 1999, Mumme et al. 1990, Bowman unpublished). However, negative demographic performance might have occurred because there were too many tall shrubs and trees. Our new findings suggested that edge territories (territories in reserves along edges of human cultural landcover types but not roads) that were optimal (primary or secondary with an optimal arrangement of scrub height) were not population sinks and even functioned as population sources. We expect there could be a broad range of variation among reserve edges because of the complexity of possible edge effects (Mumme et al. 2000, Bowman and Woolfenden 2001, Schoech and Bowman 2001, Reynolds et al. 2003, Fleishcer et al. 2003, Reynolds et al. in press, Thorington and Bowman in press). Although managers often prefer to leave buffers along edges, we emphasize the importance in managing habitat to be optimal beginning at the border of potential reserves because of the relatively low number of core territories in most large reserves.

We agree with Bowman (2001; personal communication) that our poor understanding of edge-effects is one of the most important data gaps for conservation planning. Bowman (unpublished) showed that even areas with low human population densities were population sinks that could only persist with immigration. Given that jays tend not to immigrate into many of these areas from reserves (Thaxton and Hingtgen 1996, Bowman unpublished), much of the entire range of the Florida scrub-jay could collapse (Bowman 2001). If this is widespread and cannot be changed, we are purchasing conservation lands in many of the wrong areas because most areas lack enough core territories to sustain losses along the edges of reserves. If true, we should only be performing Florida scrub-jay conservation in the largest of the remaining potential scrub reserves that have an abundance of core territories.

One reason why areas with low human housing densities were population sinks in Bowman's study was that habitat quality was poor because much habitat was tall and unburned, and it was not possible to partition variance in habitat quality effects from additive effects associated with the human landscape (Bowman unpublished). Our study had potential to partition the variances associated with different factors because many territories occurred within suburbs, because a large number of territories occur in potential reserves adjacent to different types of human edges, and because many territories occurred distant from edges. To date, only limited conclusions can be made because many reserves only approached optimal at the end of the study. We emphasize caution in drawing conclusions that are broadly applicable.

The arrangement of height within territories was clearly the most influential factor influencing demographic success. The results were consistent in suggesting that territories with only short or only tall scrub were population sinks (Woolfenden and Fitzpatrick 1984, 1991; Breininger and Oddy 2001, Breininger and Carter 2003). The results for tall mixed scrub depended on landscape context. Primary and secondary territories with tall mixed scrub had reproductive success that matched the mortality rate. This differed from studies on KSC that indicate that tall mixed scrub is a population sink (Breininger et al. 1998a, Breininger and Carter 2003) but is similar to studies on Cape Canaveral Air Station (Stevens and Young 2002). We suspect that other habitat factors, such as openings and the abundance of xeric soils might explain these differences because of compensatory effects (Burgman et al. 2001). Nevertheless, recovery depends on population expansion, which requires a large number of territories that produce an excess of breeders. Therefore, management should not be judged as successful when there is an abundance of tall mixed scrub.

Almost all territories occurred in suboptimal habitat, which explained the population decline. However, Florida Scrub-Jays that resided in optimal habitat were successful and a large number of territories in optimal habitat could sustain a large number of territories in suboptimal habitat making potential populations large enough to withstand catastrophic events such as epidemics (Root 1998, Breininger et al. 1999aa, Stith 1999, Breininger and Oddy 2001, Breininger and Carter 2003). Habitat arrangement clearly influenced population dynamics, but our abilities to partition variance among many variables were limited by a low sample size of optimal territories. Sample sizes of optimal territories began increasing in 2001 and 2002 within many territory clusters. Partitioning variance among many potential factors (oak cover, height, tree densities, edge effects, experience, presence of helpers, annual variation) is an important investigation but we believe such an investigation should focus on territories that approach optimal and not where many habitat variable are marginal.

All evidence indicates that recruitment only exceeds mortality in recently burned areas with enough optimal height oak scrub and low tree densities (Woolfenden and Fitzpatrick 1984, 1991; Breininger and Oddy 2001; Breininger and Carter 2003). Long-term persistence depends on population recovery to increase population size within conservation areas. Population growth requires recruitment to significantly exceed mortality and therefore requires optimal height arrangements.

Dispersal Mean dispersal distances were greater than those in unfragmented landscapes (Woolfenden and Fitzpatrick 1984; Breininger and Carter 2003), as expected (Thaxton and Hingtgen 1996, Breininger 1999, Fitzpatrick et al. 1999). In just two years of study in Central Brevard we observed exchanges with South Brevard. Based on the dispersal distances observed and the presence of potential habitat, we eventually would have expected rare exchanges between Central Brevard and North Brevard.

Dispersal in Florida Scrub-Jays might best be explained by two opposite strategies: “delay and foray” and “depart and float” (Stith 1999). The delay and foray strategy explains most dispersals where nonbreeders make short forays to investigate vacancies within an assessment sphere. The depart and float dispersal strategy is most common among birds, but not among Florida Scrub-Jays. The depart and float strategy entails greater risks, especially if unsuitable habitat must be crossed (Stith 1999). We observed 16 Florida Scrub-Jays that we described as floaters. Most of these occurred in Palm Bay and seemed to remain in Palm Bay after the 1997 epidemic. We also observed a few floaters for a few years in very tall habitat surrounding Valkaria airport. Here, we describe floaters as birds that were never seen associated with a particular territory but known to be alive because they were occasionally sighted in different locations. These individuals were rarely observed to have left the territory cluster.

Many of the birds that left a cluster to become breeders in another cluster were not observed to be floaters but disappeared for several months and were re-sighted in another cluster. Many of these left clusters that had vacant territories suggesting that some exchange among territory clusters is likely.

We observed only two emigrants from the relatively large Palm Bay population, which resided in poor quality suburbs that we thought would be a source of immigrants into reserves. We observed two movements from reserves into urban fragments. Each of these came from reserve scrub patches that had few contiguous territories. Unbanded jays that immigrated into our study tracts were usually very tame upon arrival and easily captured leading us to believe they were not any of the unbanded residents we were frequently attempting to capture. We believed that many of the immigrating jays came from suburbs because they were very tame. Jays in residing in large scrub tracts areas were usually unfamiliar with peanuts and cautious at first.

There are many ideas about factors that influence dispersal rates dispersal among populations (e.g., density-dependence [Akçakaya 2002], metapopulation theories [Harrison and Taylor 1987, Hanski 1999] and ideas that it is adaptive for small populations to have greater exchange of individuals than large populations [McPeek and Holt 1992, Doncaster et al. 1997, Diffendorfer 1999]. We have not yet tested these alternatives because of many possible alternative models and the lack of a large sample size of exchanges.

We emphasized demographic responses to fragmentation because the genetic consequences are usually less immediate threats (Holsinger and Vitt 1997). There is a large gap in understanding differences between the movement of individuals and genes (Antonovics et al. 1997; Sork et al. 1998). Across long time periods, each metapopulation on the mainland of Florida’s Atlantic Coast might be too small if their populations continue to decline and extirpation occurs within the intervening fragments. Theoretical models suggest that a small amount of population exchange can substantially reduce these threats (Efford 1996). Our results suggested a small amount of exchange occurs. Even a small amount of exchange influenced the colonization of territories following restoration. Based on the exchange observed and the slow pace of acquiring and restoring reserves to optimal habitat quality, we do not recommend translocation. The exception, however, occurs north of Buck Lake where there is an abundance of potential territories and very few Florida Scrub-Jays available for recolonization. Translocation there might be an important option after habitat is acquired and restored.

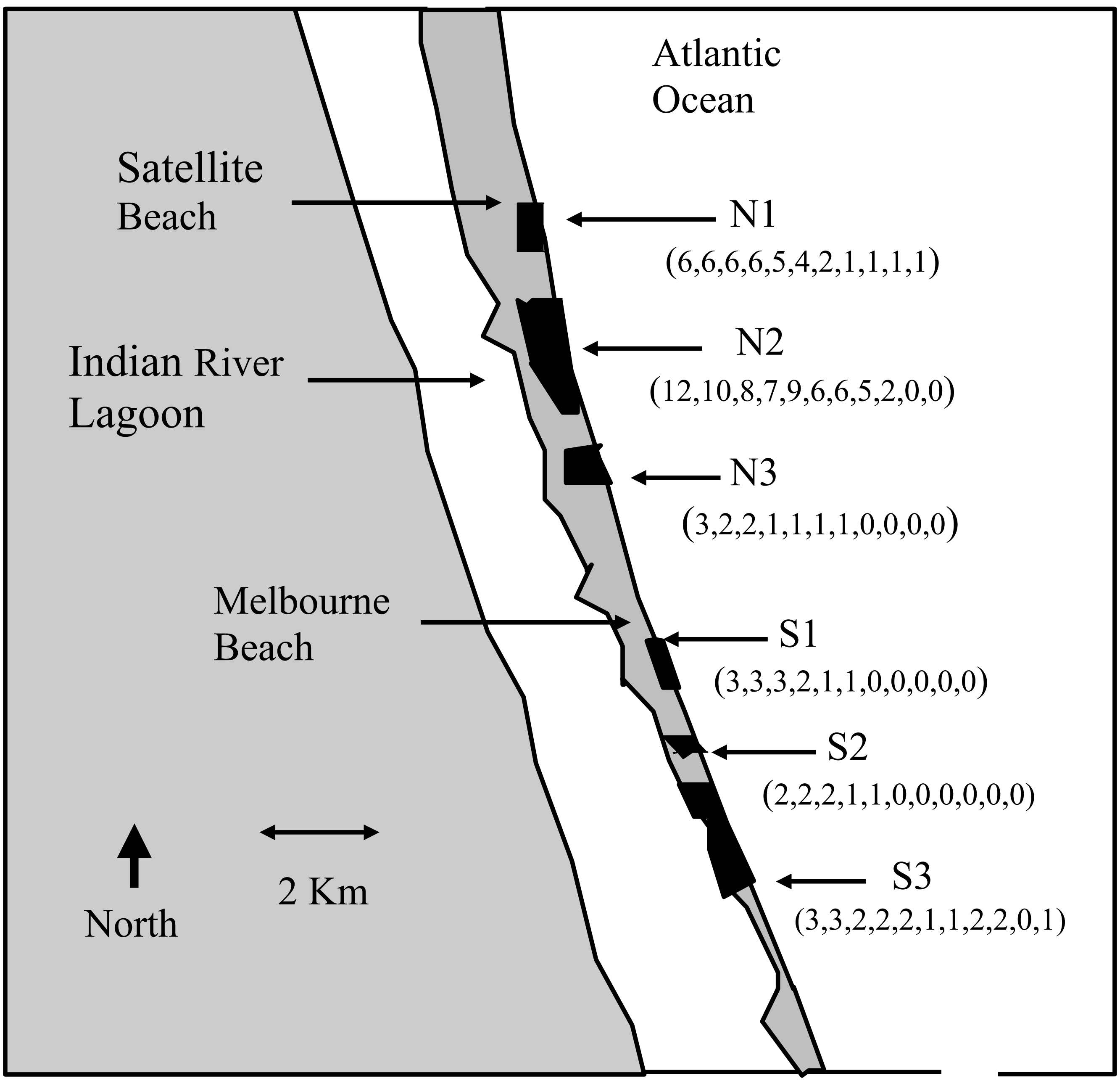
5.0 South Beaches Metapopulation Study Update

The purpose of this section is to update relevant material and not summarize what is examined in detail elsewhere (Breininger 1999) and used to support recovery team population modeling (Stith 1999). Current population size includes only 2 breeding pairs (Figure 11) suggesting that extinction is inevitable. A pertinent finding of our South Beaches study was that we observed frequent dispersals among population clusters and subpopulations and at least one dozen exchanges where Florida Scrub-Jays must have crossed > 4.2 km of contiguous urban areas. An interesting observation was that Florida Scrub-Jays in the Coconut Point EELs reserve had been extirpated but was recolonized shortly after it was burned. The male that recolonized the site was from another subpopulation indicating that recolonization by males can occur. Extirpation probably again occurred because the habitat quality was poor, a busy road intersected the reserve, and the overall population size was very small.

6.0 Management Recommendations

Habitat management Fires will rarely produce a landscape with only optimal territories but recovering populations requires maximizing the proportion of optimal territories. Habitat management and restoration must address habitat suitability at the territory scale because territories are the functional demographic units within landscapes (Breininger and Carter 20003). Most populations declined because there were too many marginal territories that included tall scrub. Because tall patches are difficult to eliminate by mosaic fires without first cutting them, cutting must be applied to specific patches of tall scrub throughout most of the landscape or an extensive fire must be applied that burns nearly all scrub. Florida Scrub-Jay population declines can occur after extensive fires but these can be followed by population growth (Breininger and Oddy 2001). Extensive fires occurring once every 20 years might be useful because they burn nearly all areas, including those resistant to fire (Breininger et al. 2002). Results here suggested that short territories might have greater negative demographic success than tall mix territories and tall mix territories might have recruitment that matches mortality. The demographic success in tall max territories appears to be site specific. If so, extensive burns in areas where the population is near carrying capacity might be disadvantageous if tall mix territories are not sinks and have much greater demographic success than short territories. Extensive burns might be essential in areas where tall mix territories are sinks (Breininger and Carter 2003). Population sizes are usually well below carrying capacity so that initial aggressive approaches are recommended to expedite restoration to a landscape of optimal territories as quickly as possible. Florida Scrub-Jays can defend relatively large areas so that extensive burns may have little negative impact in areas with few territories relative to habitat potential but the long-term benefit of extensive fires might be substantial as the population recovers.

Figure 21. Location of Florida Scrub-Jay Territory Clusters, North (N) and South (S) Subpopulations on the Barrier Island of South Brevard County (Breininger 1999). The Numbers in Parentheses Refer to the Number of Breeding Pairs from 1992 to 2002.



Once restored, frequent mosaic fires are the best mechanism to maintain openings and still keep a few acres of oak scrub at 120-170 cm within each territory (Breininger and Oddy 2001, Breininger et al. 2002). Open sandy areas are microhabitats important to Florida Scrub-Jays (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995) and many specialized plants (Menges and Hawkes 1998). Most open sandy areas do not persist in scrubby flatwoods for more than a few years after fire (Schmalzer and Hinkle 1992a, Hawkes and Menges 1996). Frequent fires that originate in mesic flatwoods or marshes and burn into oak scrub represent one mechanism to retain open sandy areas. Conventional wisdom holds that natural fires frequently occur within Florida landscapes but that fires often burn out upon entering scrub oaks where flammability is lower (Webber 1935, Myers 1990, Breininger et al. 2002).

Many landscapes have become forests or otherwise have too many tall trees so that timbering also is an option. Reserve edges should also be optimally managed.

Restoring and managing scrub for Scrub-Jays will benefit other species of conservation concern and is not single species management (Means and Campbell 1981, Speake et al. 1978, Auffenberg and Franz 1982, Layne 1990, Breininger and Smith 1992, Menges and Kohfeldt 1995, Hawkes and Menges 1996, Menges and Hawkes 1998).

Reserve Design Conservation reserve designs should include secondary and tertiary ridges and adjacent mesic flatwoods as potential habitat, because they contribute to population stability by making overall populations larger (Pulliam 1988, Howe et al. 1991). Secondary and tertiary ridges are often not specified as part of the scrub ecosystem (Schmalzer et al. 1999) and are often excluded from Florida Scrub-Jay conservation reserve designs (Root 1998). Mean demographic rates provided herein can approximate the proportion of sink territories that can be supported by source territories, although these approximations are probably best done using population models that consider additional complexities, such as stage-specific vital rates, environmental stochasticity, and catastrophes (Burgman et al. 1993).

It is not necessary to explicitly map scrub oak ridges to apply these results. One can grid landscapes into potential territories using geographical information systems and categorize the habitat potential of individual grid cells to determine the potential arrangements of sources and sinks in conservation reserve designs.

Below we provide a general comment on the relative importance of every PRU. Although many sites by themselves might not be designated high priorities, recovery requires conservation of most of the units to achieve population viability. Priorities (Figure 22) assumed that it was most important to maximize the number of contiguous territories and connectivity among reserves while keeping the proportion of fragmented territories to a minimum. The draft recovery plan provides further guidance.

PRU 1. Much was forested prior to the 1998 wildfires, which burned large areas. Although most of the unit is mesic, there is potential for 10 core territories. Surveys might have underestimated population size because of its and limited access although we doubt that many families occur because it was forested before 1998. Habitat potential and possibly Florida Scrub-Jay population size have been underestimated in

South Volusia County. The possibility of connecting the North Brevard metapopulation to the Merritt Island-S.E. Volusia metapopulation should be explored.

PRU 2. Much of this scrub borders a highway and it can only support a couple pairs. Much of the site is oak scrub but its small size and lack of core territories does not make it a priority for conservation.

PRU 3. Much was forested before the 1998 wildfires, which burned large areas. The unit has a potential population size of 30 territories, including a large number of core territories. Surveys might have underestimated population size because of limited access. We doubt that many families occur there because it was forested before 1998. Acquisition of this site should be of high priority to maintain it as a large natural landscape. It occurs within a region of high conservation potential determined by Florida Greenways studies (Tom Hoctor, University of Florida, personal communication). This might be a good site, combined with Buck Lake, for a translocation experiment.

PRU 4. This site is east of PRU 3 and is mostly mesic but could provide habitat for several core territories. Population size in 1992 might also have been underestimated. We recommend that the conservation potential of this site be closely evaluated, because it is not in an existing conservation proposal. We recommend the site for Florida Scrub-Jay conservation as a moderate priority. It will be important to acquire most or all of the site to maximize its potential value given that it is separated from PRU3 by a highway and bounded to the east by suburbs. .

PRUs 5, 6. This area has potential to support a few territories in a fragmented landscape.

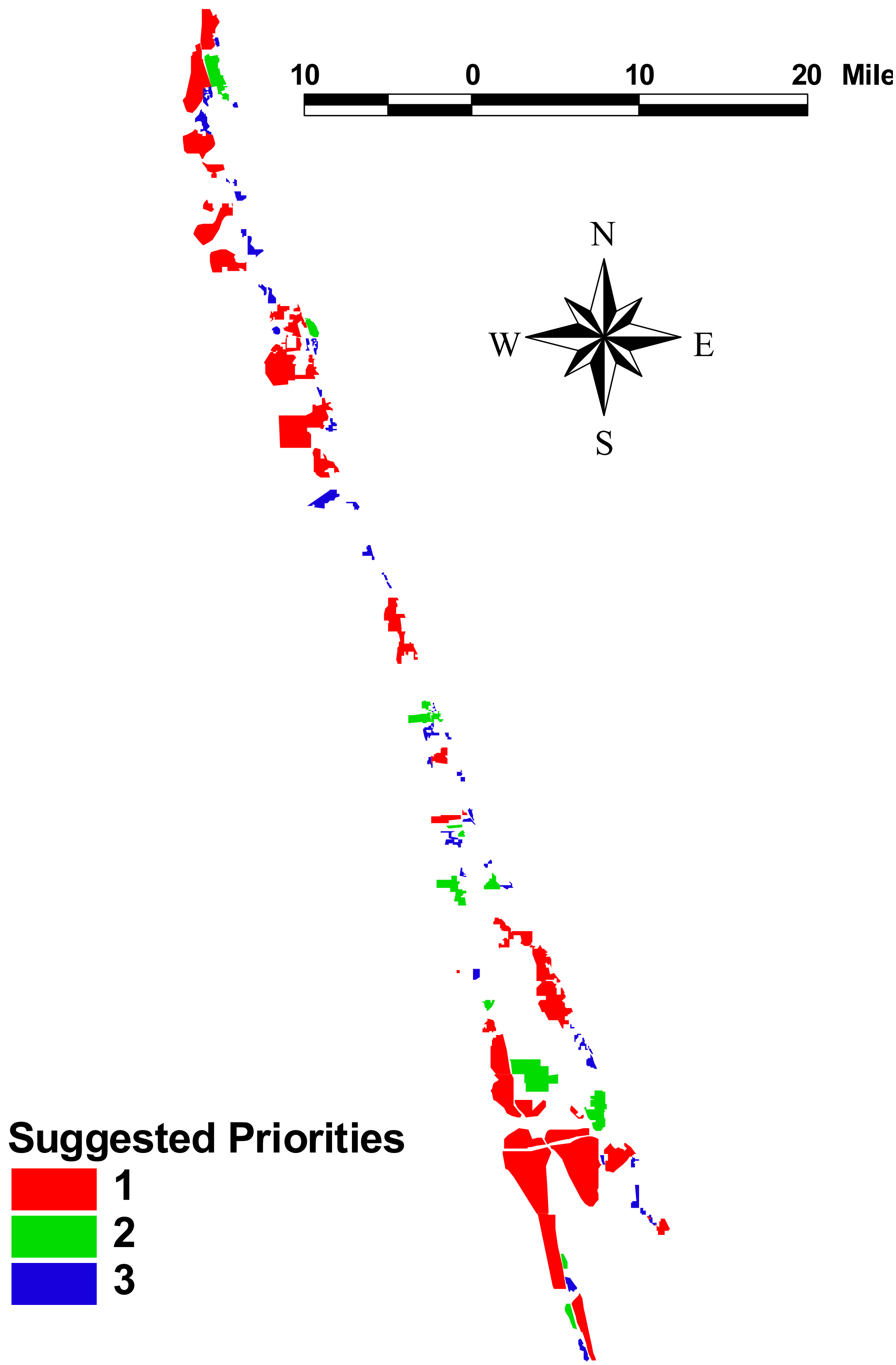
PRU 7. This area has potential to support only 1-2 territories in a landscape fragmented by agriculture.

PRU 8. This area has potential to support several territories in a fragmented landscape but it has potential connective value.

PRU 9. This area includes the Buck Lake Conservation Area that burned in 1998 and has been subject to many restoration efforts since then. Some habitat remains available for purchase within this area. We consider this additional purchase to have high priority because of the importance of sustaining core populations and because the population sizes in northern Brevard are precariously close to extinction. This would be a good site for translocation because population size has dropped to 2 territories and there are few potential colonists nearby.

PRU8. This includes scrub in the southern end of Buck Lake Conservation Area and is badly overgrown but could be an important link to Seminole Ranch Conservation Area. Some additional habitat could be purchased but it would be almost surrounded by human development. Restoration of scrub in conservation ownership should be a top priority.

Figure 22. Possible Reserve Design.



<u>PRUs 11, 12, 13</u>. These units have territories within a fragmented landscape.

<u>PRU 14</u>. Most of this unit is part of Seminole Ranch Conservation Area badly needs habitat management.

<u>PRU 15</u>. This unit could support 17 territories. Most of this unit is part of Seminole Ranch Conservation Area but it badly needs habitat management, which should be a top priority. The Florida Fish and Wildlife Conservation Commission is the lead agency responsible for habitat management. Purchasing the remaining areas should be a top priority because many would be core territories and they would maximize potential population size, which is needed to sustain population viability.

<u>PRUs 16, 17</u>. These habitat fragments, surrounded by suburbs, can only support a few territories.

<u>PRU 18</u>. The area South of South Lake and mostly west of Fox Lake is within a proposed CARL boundary and could support about 20 territories in a predominately natural landscape connected to the Seminole Ranch Conservation area. Therefore, this should be a top priority for conservation.

<u>PRU 19</u>. This small habitat fragment can support 5 territories.

<u>PRU 20</u>. This area includes the Titusville Well-Field and a site purchased by EELs. There are some areas that still should be acquired. Most of the site has not been managed. Restoration should be a top priority given that it could support about 14 territories but only 2 remain occupied by Florida Scrub-Jays.

<u>PRU 21</u>. Some of this area is within proposed and existing EELs sanctuaries, including the Enchanted Forest. It has potential to support 17 territories and has connective value, although suburbs or forest would border most territories. We suggest it is of moderately high priority even though most of it is unoccupied.

<u>PRU 22</u>. This fragment is surrounded by suburbs and highways and has potential to support contiguous 14 territories but only two occupy the site.

<u>PRU 23</u>. This area is surrounded by suburbs but could support one territory.

<u>PRU 24</u>. The area surrounding Tico Airport has potential to support 55 territories. Acquiring large portions of this area should be a top priority because of the large potential population size and its connective value.

<u>PRUs 25, 26, 27, 28, 30</u>. These habitat fragments are bordered by roads but have potential habitat to support several territories.

<u>PRU 29</u>. This area along Grissom Road provides habitat for about 30 territories, although road mortality along roads is a concern. A portion of this area has been bought for conservation under the Grissom Road Mega-Parcel.

<u>PRU 31</u>. This area along Grissom Road and north of Cocoa is the southern terminus of the North Brevard population making it a top priority to maintain opportunities for exchange with the larger southern metapopulations. It has potential to almost 20 territories but has not been proposed for conservation.

<u>PRU 32</u>. This area surrounding Mud Lake has potential to support 6 territories but these potential territories are unoccupied because the area has become forest. This site has local conservation interest because it is one of the few natural areas remaining in the City of Cocoa. It could have value to connect metapopulations.

PRUs 33, 34, 35. These small fragments could support several territories but none are known to be occupied, although these could be restored and might have value in linking metapopulations.

PRU 36. This is the single most critical polygon in Central Brevard because it is inhabited by one the largest populations and it has some of the best habitat quality. Almost half is part of the EELs Cruickshank Sanctuary and the Viera Mitigation Site. Significant portions are at great risk to development. Given this is the critical core for Central Brevard, the opportunity to link metapopulations probably depends upon the viability of this unit and therefore we recommend it be given a top priority for conservation.

PRUs 37- 46, 48. The habitat fragments near Wickam Road once could support 20 territories but habitat is rapidly being lost to development.

PRU 49. This habitat fragment could support 8 territories and much or all of the habitat is part of Wickham Park. Developing a conservation plan for Wickam Park should be a top priority because of its importance in connecting metapopulations.

PRUs 49, 50, 51. These habitat fragments could support a few territories.

PRUs 52, 53, 54, 55, 56, 57. The potential population size around Melbourne Airport exceeds 20 territories making conservation of at least some of the PRUs a top high priority for linking metapopulations.

PRUs 58, 59, 60. These habitat fragments can support few territories.

PRUs 61, 62, 63. Each of these can support many territories and they are the deciding links determining whether the small and vulnerable Central Brevard is a separate metapopulation from the South Brevard-Indian River-St Lucie metapopulation based on criteria described by Stith et al. 1996. No conservation proposals address conservation in these areas but their fate needs immediate evaluation, depending on recovery plan criteria.

PRU 64. This includes the Turkey Creek and Malabar Scrub Sanctuaries. Most of the unit has been acquired; extensive habitat restoration should be a top priority.

PRU 65. This includes the Jordan scrub sanctuary and Waterside Downs mitigation area. There are about 16 additional potential unprotected territories that are a top priority because they would provide a critical link between the Malabar Scrub Sanctuary and Valkaria. The Malabar-Grant-Valkaria has the greatest potential to be the largest, contiguous remaining subpopulation along the Atlantic Coastal Ridge, which once stretched along nearly all of Florida's east coast.

PRU 66. This PRU near Brevard County Community College has potential to support a Florida scrub-jay territory.

PRU 67. This area established for scrub-jay conservation at Liberty Park could support one territory.

PRU 69. This habitat fragment east of the Palm Bay suburbs has enough habitat to support 6 territories. The site is proposed for conservation and might be an important connector. Some of it is an EELs sanctuary that badly needs management and has a private landowner interested in conservation.

PRU 68. Much habitat is public ownership although considerable amounts remain to be acquired. Conservation plans that restore more habitat at Valkaria Airport and the Habitat Golf Course are needed. Core territory integrity is uncertain because of a potential Florida Inland Navigation District (FIND) Spoil Site. This site has the necessary permits to destroy the potential core of the Valkaria Scrub Reserve. FIND has expressed willingness to shift the site. Several of the problems in moving the site have been associated with nearby wetlands, which are disturbed and have no regional significance in contrast to the importance of maintaining this last remnant of an Atlantic Coastal Ridge Scrub Ecosystem.

PRUs 71, 72, 74-77. These habitat fragments could support a few territories.

PRU 70. The proposed Babcock Sanctuary can support 8 territories. Much of the site is proposed for conservation and has been used for mitigation. Much of the site used for mitigation is approaching optimal conditions.

PRU 73. This area can support almost 22 core territories. Much habitat south of Grant Road has been used for mitigation and has been restored. A large tract of contiguous scrub occurs just north of the Micco Scrub Sanctuary should be a top priority for conservation.

PRU 78. This might support a few territories with restoration and might facilitate exchange between Atlantic Coastal Ridge and Ten Mile Ridge populations once restored. Most has been acquired by EELs.

PRU 79. This area can >35 territories and comprises the Micco Scrub Sanctuary and North Sebastian Buffer Reserve. Restoration has been completed on Sebastian Buffer but additional mechanical cutting and burning is still needed on the Micco Scrub Sanctuary.

PRU 80. The area south of Micco could support 10 territories and has moderately important value in connecting subpopulations.

PRUs 81, 82. These areas on north Sebastian Buffer Reserve could several territories. Restoration would need to include the intervening pine flatwoods. Restoration should have long-term value by connecting subpopulations although there is no immediate need.

PRU 83, 84. These areas on north Sebastian Buffer Reserve can support almost 20 territories but the landscape share habitat with one of the last Red-Cockaded Woodpecker colonies within the region and it is precariously close to extinction. Although habitat requirements overlap optimal pine densities differ between species. We recommend actions that only benefit both species rather than maximizing carrying capacity for Florida Scrub-Jays only. Reduction of hardwood trees near the North Fork of the Sebastian River could benefit both species.

PRU 85. The Coracii portion of Sebastian Buffer, heavily degraded by agriculture, can support >35 territories and much restoration has begun. Most territories remain marginal because the recently burned scrub is interspersed by forest and tall scrub. The Sebastian Area-Wide Florida Scrub-Jay Habitat Conservation Plan (Sebastian HCP) reserves occur within dispersal distance of Coracii. A wide open landscape should be restored along much of the northern and eastern border to enhance exchange with the northern part of the buffer and the Sebastian Highlands.

PRU 86. Detailed state-of-the-art management plans were developed as part of the Sebastian HCP (Smith Environmental Services 1999). This area also includes some mitigation land and areas that have not been proposed for conservation. This areas could connect PRUs 85 and 86. The entire area could support >10 territories and maximizing population size should be a top priority.

PRU 87. The Carson Platt portion of the Sebastian Buffer Reserve is the largest contiguous stretch of habitat approaching optimal habitat quality found anywhere along Florida's Atlantic coast. There is enough habitat for approximately 40 territories. Many patches of tall scrub need fire and the area would benefit most by targeting these patches and burning the rest with mosaic fire. The mesic flatwoods east and west of the scrub ridge need hot fire. There is much hardwood invasion of swales and mesic flatwoods along the northern edge that could be reduced to enhance connectivity.

PRU 88. A local park and some additional overgrown scrub along the South Fork could be restored to enhance connectivity between Sebastian Airport and Sebastian Buffer Reserve.

PRU 89, 90, 91, 93-96. These PRUs include the Sebastian Highlands HCP. Several additional properties (Water Management District, Wabasso Golf Course) that could be acquired or managed to enhance the HCP. Populations in these areas precariously close to extinction.

PRU 92, PRU 97-101. A top priority should be given to acquire and restore all of these units as a contiguous scrub and flatwoods landscape separated by Interstate 95. The oak and palmetto-oak is not contiguous so that the landscape was subdivided into units for prioritizing each of them. The number of territories that could be supported is approximately 50. The only areas in conservation include the Sand Lakes Restoration Area, which can support 5 territories. The SJRWMD has been restoring this landscape (Sean Rowe personnel communication). No other conservation lands proposals include these areas so that developing acquisitions should be a top priority. The most important units are PRU 92 and 98-100.

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